POWER

No. 43 NEW YORK, JANUARY 4, 1916 No. 1

NOW that the old year is ended,
Now that you've entered the new,
Won't you agree that it's time you attended
To things you've neglected to do?
Most of your noble intentions
Died in their childhood, and so
Added a bit to the growing dimensions
Of paving in regions below.

You, Mr. Power-Plant Owner,
Turn your thoughts in on yourself.
Haven't you acted the part of postponer
While striving to pile up your pelf?
Now that your memory searches
Deep in the nooks of your brain,
Don't you recall that you promised to purchase
Equipment again and again?

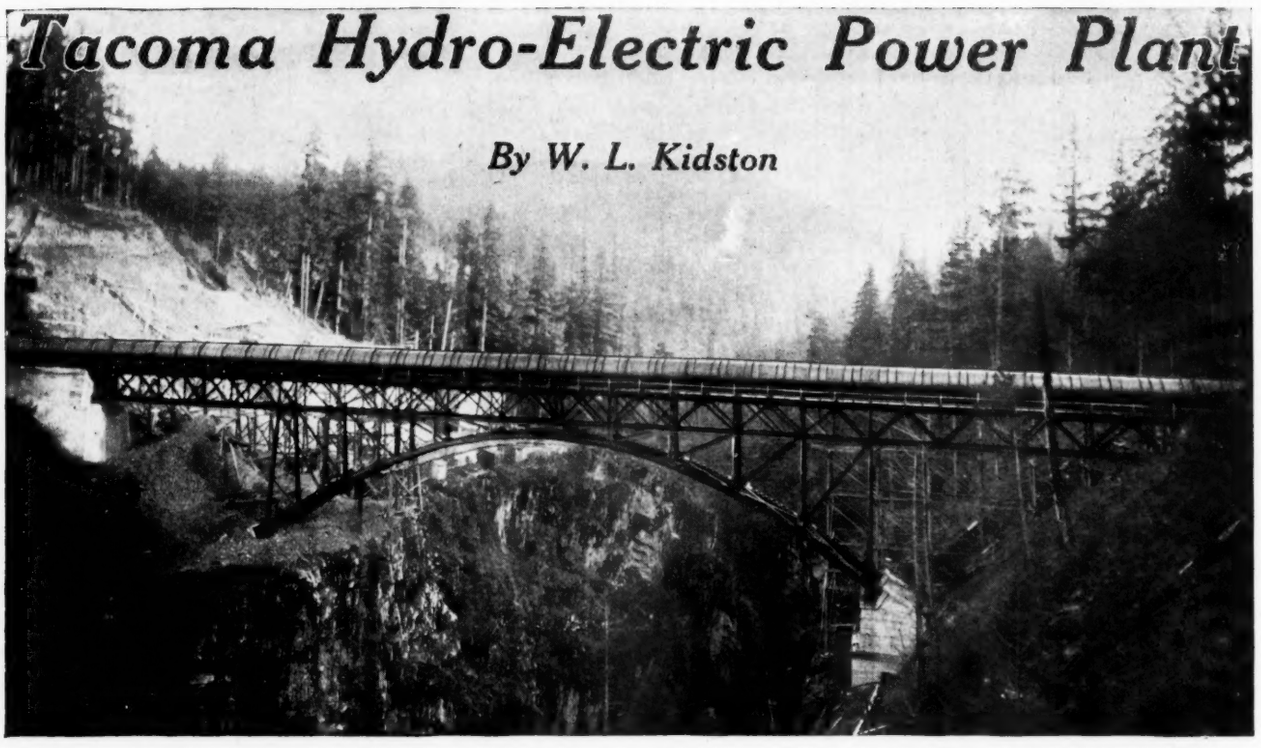
Wasn't there talk of a meter,
Maybe a flue cleaner, too?
Didn't you think of installing a heater
And stokers before you were through?
But, as your business expanded,
Somehow the rush and the grind
Caused all the things that the chief had demanded
To vanish clean out of your mind.

Now that your cashbook and ledger
Show such a handsome amount,
Isn't it time to quit being a hedger
And render the chief an account?
Issue those orders for shipment!
Let not a moment be lost!
You'll be surprised how the modern equipment
Will lessen both labor and cost.

Contributed by RUFUS T. STROHM, *Scranton, Pa.*

Tacoma Hydro-Electric Power Plant

By W. L. Kidston



SYNOPSIS—This hydro-electric plant of 20,000 kv.-a. capacity has four 5,000-kv.-a. generators each driven by an 8,000-hp. turbine waterwheel operating with an effective head of 415 ft. It was built at a cost of $55.14 per hp. The total cost of the plant, including the substation, transmission lines and general expenditure, was $2,354,984.35.

The hydro-electric power plant built for the City of Tacoma, Wash., at the extremely low cost of $55.14 per hp. is situated on the Nisqually River about thirty-three miles south of the City of Tacoma, Wash. The generator-room floor is at an elevation of 535 ft. above sea level. The dam, intake and settling basin are located about three miles above La Grande station of the Tacoma Eastern Railroad. The dam is of concrete construction with a maximum height of 45 ft. and a spillway of 260 ft. It provides a storage basin of about 80,000 hp.-hr. capacity. The intake, racks, washout and regulating gates and settling channel, which last is 780 ft. long, 40 ft. wide and about 20 ft. deep, are located on the west side of the dam, and from the lower end of the settling basin the water is carried through an 8x8-ft. tunnel 10,000 ft. long to a point on the Nisqually River about 1,000 ft. above La Grande station. From here the water is carried across a steel bridge (see top view) and through a concrete conduit to the regulating reservoir. The tunnel and conduit have a capacity of about 800 cu.ft. per sec. The regulating reservoir, Fig. 1, which is roughly 494x500 ft.

FIG. 1. FOREBAY AND GATE HOUSE OF THE TACOMA HYDRO-ELECTRIC POWER PLANT

has a capacity of 3,020,000 cu.ft. available for use during peak loads and an area of 247,000 sq.ft. The maximum elevation of water in the reservoir is 940 and the minimum, 925 ft. The top of the pressure pipes are submerged 4 ft. at the minimum elevation of water in the reservoir. Fig. 2 is a plan of the headwork on the Nisqually.

is 20 ft. and the maximum fluctuation between high and low tail-water level is 13 ft. above normal, with no fluctuation below normal as a tail weir is provided. Fig. 3 is a profile of the pressure pipes.

In specifying the turbines they were called to be most efficient at a total effective head of 415 ft. when running

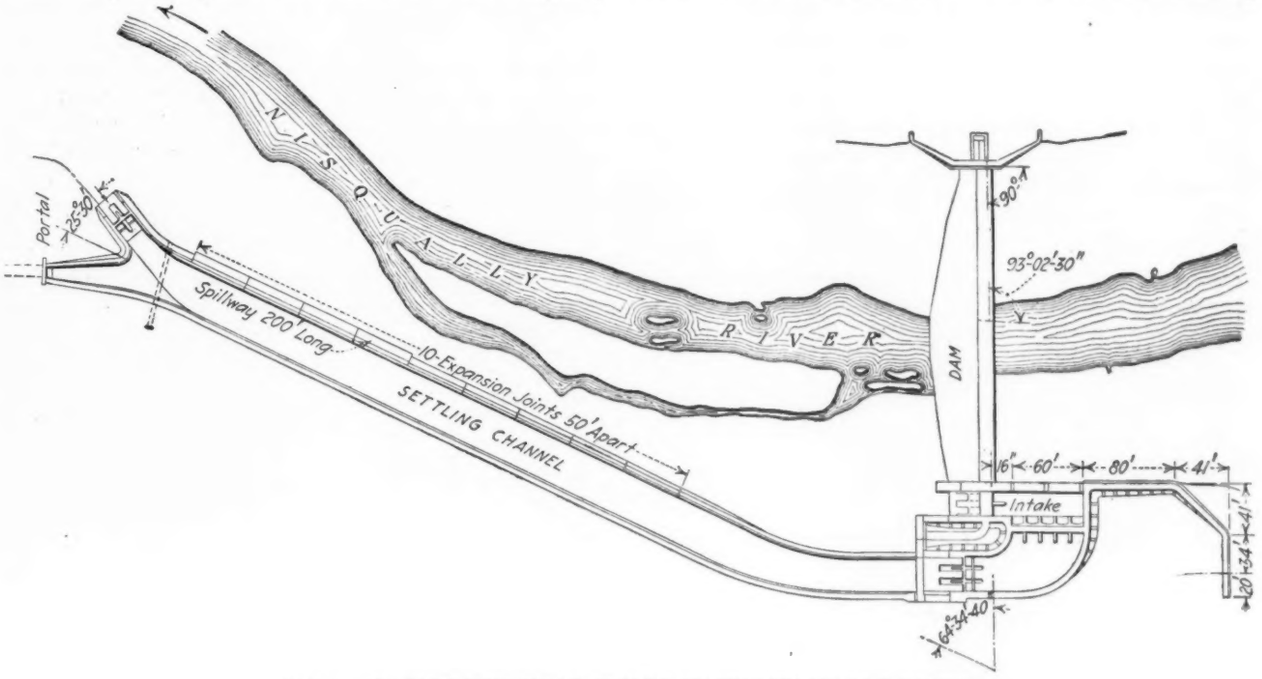


FIG. 2. PLAN OF THE HEAD WORKS ON THE NISQUALLY RIVER

The power house consists of three buildings of the common wall type of construction of concrete and brick, with galvanized-iron roof supported by steel roof trusses.

Each main turbine has a separate pipe line about 780 ft. long and ranging in size from 72 in. at the top to 48 in. at the gate valves in front of the turbines. The two exciter wheels are supplied from one 24-in. pipe which divides in the generator room. All pipes are of riveted

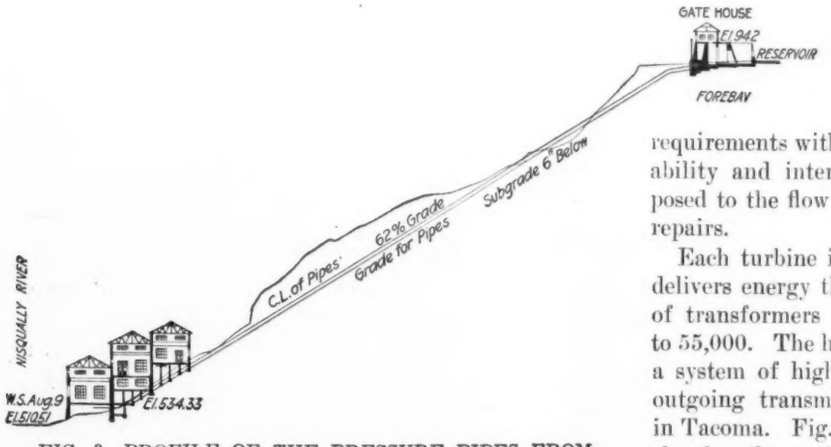


FIG. 3. PROFILE OF THE PRESSURE PIPES FROM FOREBAY TO THE POWER HOUSE

steel, and each one is provided with a vent and sluice gate at the forebay.

The static overhead is 405 ft., and the friction head in the pressure pipes is 5 ft. The effective overhead when each pipe carries the flow of water according to the maximum load of the turbine is 400 ft. maximum, 395 ft. normal and 385 ft. minimum; the normal suction head at the normal speed and load of the generators and exciter wheels at a total effective head of 400 ft. The minimum flow of water that has been recorded is about 360 cu.ft. per sec. extending over periods of never more than 24 hr., and rarely occurs. The maximum flow has many times exceeded 30,000 cu.ft. per sec. The normal flow is 400 cu.ft.

The river receives its water partly from glaciers and therefore contains glacial silt, and although provision is made both at the headworks and in the regulating basin for settling, the design of the water-wheels is such as to meet these special requirements with regard to wear and tear and the removability and interchangeability of the parts severely exposed to the flow of operating water, which will facilitate repairs.

Each turbine is directly connected to a generator that delivers energy through a system of busses to four banks of transformers where the voltage is raised from 6,600 to 55,000. The high-tension power is carried then through a system of high-tension busses and tie switches to two outgoing transmission lines 30 miles to the substation in Tacoma. Fig. 4 is a partial view of the generator room showing three of the four generators. Fig. 5 is an elevation of the plant.

There are four main turbines, each having a maximum capacity of 8,000 b.hp. at full gate opening when operating under an effective head of 415 ft. and a speed of 450 r.p.m. They are of the single-discharge, Francis, inward-flow reaction type on horizontal shafts and directly connected to the 5,000-kv.-a. generators. Two are left- and two right-hand turbines. They are equipped with pressure

regulator and provided with manholes and covers for inspection. The regulator in form is that of a true evolutionary spiral, so that the area decreases in proportion to the discharge of water into the guide case, resulting in a constant velocity with a maximum of hydraulic losses. The bronze runners are cast in one piece, the composition being 88 per cent. copper, 10 per cent. tin and 2 per cent. zinc. The peripheral speed is 65 per cent. of the spouting velocity. The thrust bearing is of the ring-tympanum oiling type and is provided with gages and drain cocks.

The end thrust on the shaft is taken up so that no adjustment is necessary during any condition of operation. Pumps and accessories are provided for the oil pressure necessary for starting operating the bearings. A cast-iron quarter-turn discharge ell is supplied and is provided with an opening for the turbine shaft packing-box, with a flange for carrying the thrust bearing. Two mainshaft stuffing-boxes and one for each guide pivot are included. The mainshaft stuffing-boxes are accessible for renewal of packing and are provided with drains to carry off all leakage. Bushings and followers are of bronze and bored so as not to act as bearings for the shaft. The steel gates, forged in one piece with pivots, are highly polished to reduce friction losses to a minimum. Each guide pivot passes through a separate stuffing-box to the outside of the turbine where they are all connected to a cast-iron shifting ring. The gates are designed so that in the event of breakage in the governor connections they will close automatically at a rate which does not endanger the wheel casing or pressure pipes. Hand-operating mechanism is also provided for the gates for emergency use. Cast-iron levers transmit the motion of the shifting ring to the gates. Equalizing pipes with throttle valves and fittings connect the runner chamber with the steel-plate draft tube and the casing with the runner chamber, so that any desired pressure within the limits of the pressure and draft heads, to suit operating conditions, may be obtained and the runner balanced. An oil-pressure governor is provided with each turbine and develops sufficient energy to move the gates freely under all operating conditions.

They are provided with a synchronizing attachment consisting of a 125-volt d.-c. motor mounted on a bracket and geared to the relay handwheel. Indicators on the governor show the percentage of gate opening. They are dead-beat in action and hold the speed within ¼ of one per cent. at constant load, and the relay is proportioned so that the difference from friction loads to full loads does not exceed 3 per cent. Each turbine is also provided with a butterfly-type inlet valve electrically and hand-operated. It is 48 in. diameter and is made with bronze seats and a bypass for filling the spiral case before opening the main valve. These valves are operated by a 220-volt induction motor to withstand the full operating head under all conditions of pressure and are capable of closing in one minute.

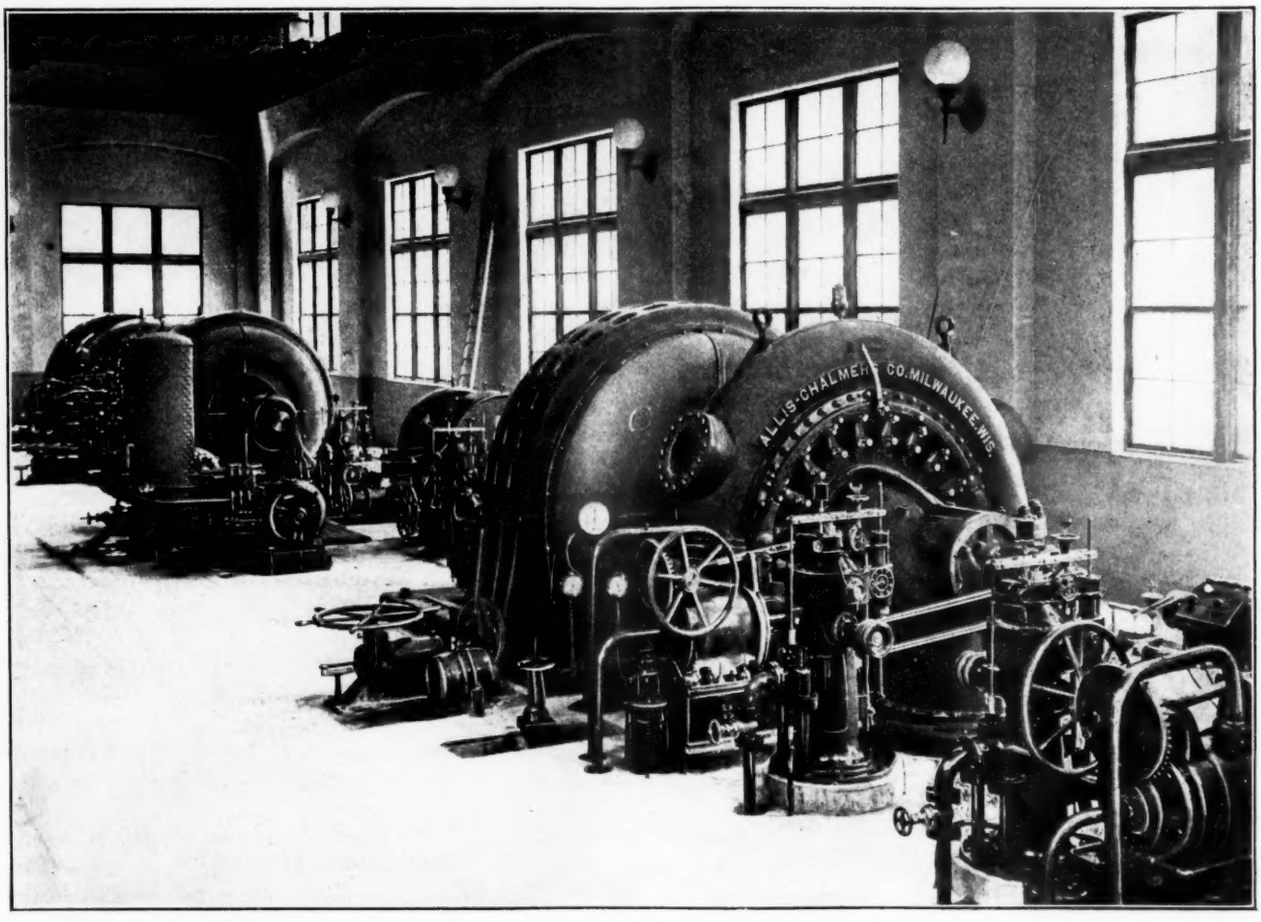


FIG. 4. VIEW IN THE GENERATOR ROOM, SHOWING THREE OF THE UNITS

Two single horizontal overhung wheels, each having a normal capacity of 300 hp. maximum at best efficiency under an effective head of 400 ft., are capable of developing 375 hp. maximum. The normal speed is 400 r.p.m. and they are directly connected to 200-kw., d.-c. exciters.

One wheel is right-hand and the other left-hand. The wheel disk is of cast steel and is balanced to a runaway speed of twice the normal speed. Each bucket is a single bronze casting securely fitted to the wheel. The wheel itself is housed in a plate-steel housing, and attachments include a cast-iron deflecting nozzle constructed in two parts, one movable and the other stationary, connected by a spherical joint. The movable section is automatically deflected by the oil-pressure governor to suit changes of load. The stationary section is connected to the 16-in. hand-operated, bronze-mounted cast-iron gate valve of the outside-screw-and-yoke type, with bypass, the water-supply pipe running under the power-house floor. A hand-regulating needle is also provided. The central oil-pressure system that supplies oil for the governors of the four main turbines and the two exciter-wheel units consists of two oil pumps driven by two 220-volt induction motors and

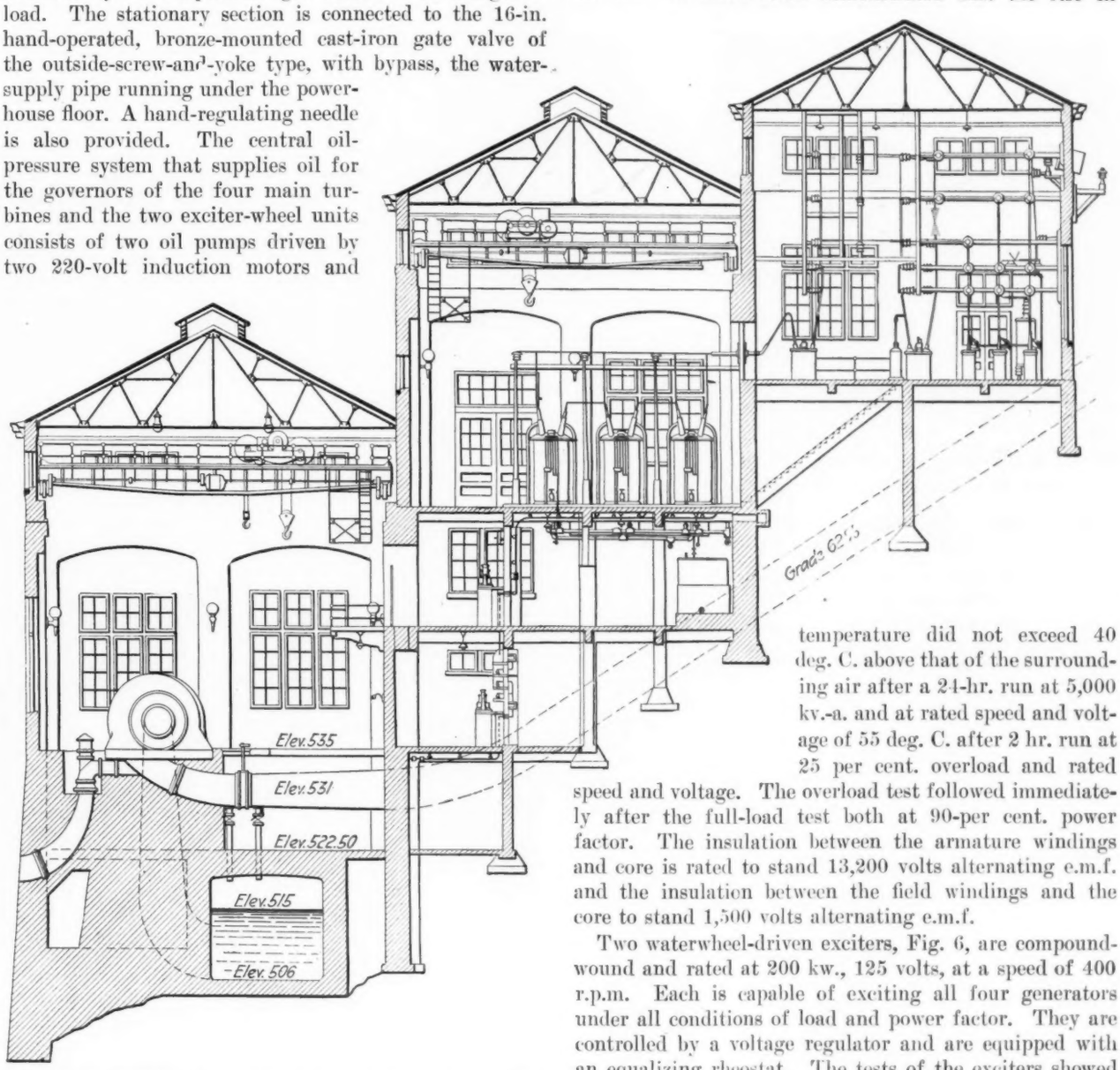


FIG. 5. SECTIONAL ELEVATION THROUGH THE POWER PLANT

one receiving tank and oil-pressure tank. All piping is seamless drawn steel tubing.

Four main generators are now operating, each of 5,000-kv.-a. three-phase 60-cycle waterwheel-driven alternators operating in parallel at 6,600 volts and 450 r.p.m., the normal operation being 90 per cent. power factor. The voltage is governed by a voltage regulator. The armature frame is of cast iron divided along the horizontal center line to permit of removability of parts by a crane. The winding is delta-connected. The machines are of the revolving-field type with a horizontal shaft extending beyond the main bearings on which are mounted the turbine runners. The bearings are of the ring-oiling type with removable shells; no oil pressure is used. Field rheostats and field discharge resistances for each machine are located in the low-tension busroom and are controlled from a handwheel on the switchboard. A bird's-eye view of the plant and pipe lines is shown in Fig. 7.

The tests for temperature and insulation conducted at the time of installation demonstrated that the rise in temperature did not exceed 40 deg. C. above that of the surrounding air after a 24-hr. run at 5,000 kv.-a. and at rated speed and voltage of 55 deg. C. after 2 hr. run at 25 per cent. overload and rated speed and voltage. The overload test followed immediately after the full-load test both at 90-per cent. power factor. The insulation between the armature windings and core is rated to stand 13,200 volts alternating e.m.f. and the insulation between the field windings and the core to stand 1,500 volts alternating e.m.f.

Two waterwheel-driven exciters, Fig. 6, are compound-wound and rated at 200 kw., 125 volts, at a speed of 400 r.p.m. Each is capable of exciting all four generators under all conditions of load and power factor. They are controlled by a voltage regulator and are equipped with an equalizing rheostat. The tests of the exciters showed after a run of 24 hr. at 1,600 amp. 125 volts and 400 r.p.m. that the temperature did not rise more than 35 deg. C. and that of the commutator not more than 40 deg. One exciter rotates in a clockwise direction and the other in an anti-clockwise direction.

There are twelve main transformers of boiler steel with cast-iron bases and covers, in banks of three transformers each with high- and low-tension sides connected in three-phase delta. The normal rating of each taken as a single-phase transformer is 1,667 kw. at 100-per cent. power factor when operating at 60 cycles. Each has a norma. voltage of 55,000 to 6,600 volts, and each is provided with four 2½-per cent. reduced-capacity primary taps. They

are oil-insulated and water-cooled, the cooling coils being without joints and tested by a pressure of 250 lb. to the sq.in. They are connected with the supply pipes under the floor. The pressure from inside the case is automatically relieved. An oil valve, oil gage, vacuum piping, indicating thermometer and oil drain with a valve are included with each transformer equipment.

The temperature rise does not exceed 35 deg. C. above that of the incoming water, which is 15 deg. C. during a 24-hr. run with a load of 1,667 kw. at 100-per cent. power factor; nor does it exceed 55 deg. C. above that of the water at 50 per cent. overload (2,500 kw.) in any two hours. The cooling water required is about 12 gal. per min. on 50-per cent. overload. The regulation is within 1.1 per cent., with normal rated load at 100-per cent. power factor and 3.3 per cent. at 80-per cent. power factor. Tests for all electrical equipment were made under the rules of the American Institute of Electrical Engineers.

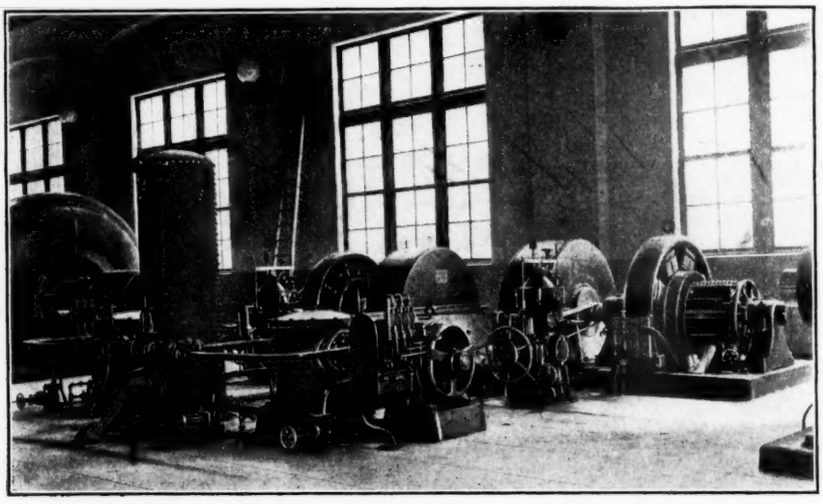


FIG. 6. VIEW OF THE OIL PUMPS AND THE EXCITER UNITS

Other high-tension equipment consists of six 300-amp. 55,000-volt choke coils of the open-air type, complete with insulators; two sets of lightning arresters of the aluminum-cell electrolytic type; thirty 300-amp. 55,000-volt disconnecting switches, and two 300-amp. 55,000-volt automatic remote electrically operated oil circuit-breakers which operate between the outgoing high-tension transmission line and the high-tension bus; four 200-amp. 55,000-volt nonautomatic remote electrically operated oil circuit-breakers, operating between the high-tension bus and the banks of transformers; and a 200-amp. 55,000-volt nonautomatic remote electrically operated oil circuit-breaker for the high-tension tie switch.

All the 55,000-volt oil circuit-breakers are of the single-pole, double-break type immersed in oil contained in steel tanks, in sets of three each, remote electrically operated by one set of solenoids and interconnected so that the three switches in a set operate simultaneously. Each switch set is separate, self-supporting without the use of brick cells. There are also four 300-amp. 55,000-volt oil-insulated current transformers with a current ratio of 60 to 1 to operate ammeters and relays on the line panels, 4 generator panels, 1 exciter panel, 1 regulator panel, 1 totalizing panel and 1 local light and power panel.

There are also eight 600-amp. 6,600-volt oil circuit-breakers (Fig. 8)—four operating between the banks of transformers and low-tension busses and four between the generators and low-tension busses; one 1,200-amp. 6,600-volt for the low-tension bus tie switch; one 100-amp. 6,600-volt for the operation between the low-tension busses and the headworks transmission line; and one 100-amp. 6,600-volt breaker between the low-tension busses and the local light and power transformers.

There are thirty 6,600-volt dry-type current transformers with a current ratio of 600 to 5 (sixteen are mounted on the main transformer leads to operate the instruments and relays on the transformer panels of the switchboard; eight are mounted on the generator leads to operate the instruments on the generator panel, four on the low-tension busses to operate the totalizing panel instruments, and two on the low-tension busses to operate with the voltage regulators) and two with current ratio of 20 to 5 mounted on the leads between the low-tension busses and the headworks transmission-line oil circuit-breakers to operate the relay for this switch. There are 22 potential transformers with a voltage ratio of 6,600 to 110 volts—eight supply the transformer panels, eight for generator panels, four for totalizing panel and two for the voltage regulators.

The generators and low tension busbars are connected by cable made of 61 No. 11 B. & S. gage copper wires. That connecting the low-tension busbars and the transformers is of 37 No. 8 B. & S. wires; 91 No. 9 B. & S. wires are used for connecting the low-tension tie current-breaker to the low busbars and 61 No. 8 B. & S. to connect the exciters to the exciter busses. For grounding the

FIG. 7. BIRD'S-EYE VIEW OF THE POWER PLANT AND PIPE LINES

high-tension lines a ground plate of No. 8 B. & S. G. copper plate 4 ft. square with a 3x¼-in. copper strip diagonally across it was used. The plant is under the direction of B. W. Collins, superintendent.

The entire cost of the system to the city of Tacoma was $2,354,984.35, divided as follows:

GENERATING PLANT

Water rights	$30,000.00
Hydro power plant, land	168,696.50
Building fixtures and grounds	208,621.33
Dam, intake, flumes, reservoirs, penstocks	1,156,728.24
Equipment	200,6 .0.66
Total	$1,764,686.73

SUBSTATION

Equipment	$85,577.20
Building, fixtures and land	110,619.40
Total	$196,196.60

TRANSMISSION

Land	$66,226.65
Equipment	118,193.23
Sundry	2.89
Total	$184,422.77

GENERAL EXPENDITURES
(During Construction of Plant)

Office furniture and fixtures	$2,993.91
Engineering and superintendence	95,866.87
Injuries and damages	85.00
Interest	83,860.47
Miscellaneous	26,872.00
Total	$209,678.25
Grand total	$2,354,984.35

To arrive at the extreme low cost per horsepower, the sum of $1,775,668 only is considered as being the total cost to produce 32,000 hp. after deducting the cost from the entire system of the substation, transmission line, water rights and power-plant land. The items of water rights and land could not be justly entered against the cost of producing 32,000 hp. because these values would vary in different localities. The high cost of land in one plant would not, when computing costs per horsepower, compare favorably in another district where low cost of land and higher construction cost would still show a lower cost per horsepower over the other, all because of land values and water rights. Considering the total cost as $1,775,668, it is found that the cost per horsepower at the Nisqually plant was $55.48.

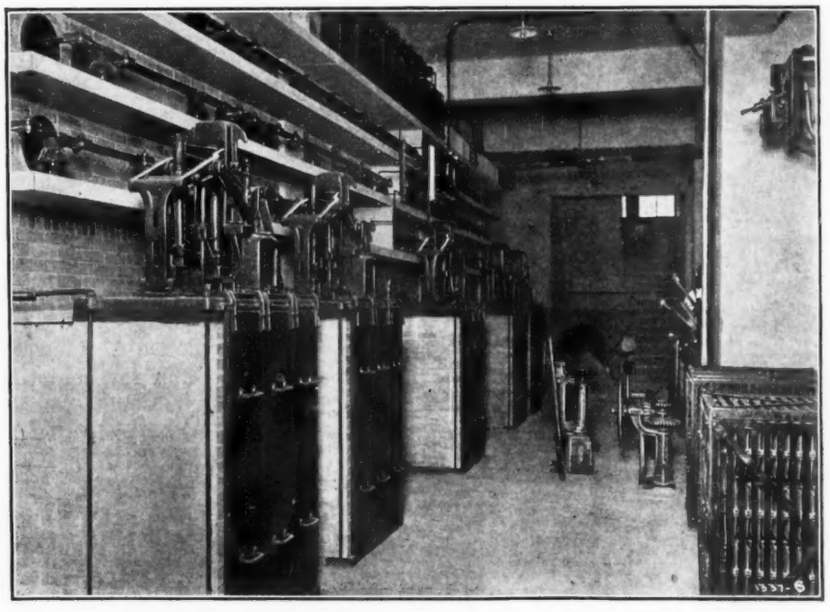


FIG. 8. LOW-TENSION OIL SWITCHES AND BUSBARS

The total receipts for 1914 were $609,348.66; operating and maintenance cost $180,503.91, or 29.62 per cent. of the total revenue, and the interest on the bonded indebtedness was $106,900, or 17.54 per cent. of the total revenue. The receipts this year will show about 20 per cent. gain.

JUST FOR FUN

Wanted—Boiler Inspectors

Does this belong in the "Just for Fun" column, or should it have a more profane heading? An employment bureau advertises for boiler inspectors with these as the principal requirements: A first-class engineer's license, technical education preferred (must also pass state examination for boiler inspectors). The position has a salary of $14 per week (more or less firmly attached), one week's salary being payable to the employment bureau for "services rendered" in advising where to apply for this *very desirable* position. What next?—E. Rector, Lynn, Mass.

A Typical Report of an Accident

The report of a boiler explosion, as published in a daily paper in "Jersey," after the opening paragraph stated that:

> The tube in the boiler had cracked, and Mr. Blank and his two boys had undertaken to plug it up while there was 40 lb. of steam on the boiler. The owner had gotten in the manhole of the boiler, and one of his sons stood on a box in front of the boiler and had driven in a rod by means of which they hoped to patch up the leaky tube and thereby prevent the passage forth of steam, when, without warning, the tube blew out, allowing volumes of hot, scalding steam to envelop the son, who stood directly in front of the tube. The owner, enveloped in a volume of steam, tried to escape from the manhole, groping for the outlet in a blind fashion, but had hardly found it before he fell unconscious on the floor, being knocked there by several pieces of flying iron.

The limit of the reporter's imagination seems to have been reached.—C. H. Dennig, Philadelphia, Penn.

[What a difference one word makes! The "manhole" was probably the combustion chamber clean-out opening.—Editor.]

Three Something Anyway

A foreign engineer, of sufficient prominence to have a town named after him, was inspecting one of our industrial power plants. Making no comment, but apparently keenly observing the turbines with synchronizing motors, steam exciter and motor-generator set, the oil switches and current transformers, he moved along to the exciter panels, glanced at the volt meters and ammeters, the Tirrill regulator and the 125-volt three-pole hand-throw switches.

"Do you use direct or alternating current?" "Alternating current, sir," answered the Chief. "Why yes, of course! Stupid of me to ask, wasn't it, when I see those"—pointing to the three-pole exciter switches—"three-phase switches?"—S. M. Quinn, Detroit, Mich.

Visits of Inspector Brown--XIII

By J. E. Terman

SYNOPSIS—Brown gets into a discussion with an engineer regarding braces and is asked questions he is unable to answer. The Chief, as usual, explains matters in an intelligent manner.

"Chief." said Brown, coming into the former's office, "I got into an argument with the engineer at Smith's furniture factory yesterday about boiler braces, and I've got an idea that he is better posted on the subject than I am.

"You see, after I had inspected a boiler, I was sitting on the steps leading to the engine room, figuring out the allowable pressure, when along came the engineer and sat down beside me. You know that boiler is a new risk, although we had it on our books once before and Jones cautioned me to look out for the bracing, as it was weak and liable to fix the pressure for the plant. The engineer asked me what I was figuring, and I told him it was the safe pressure that could be allowed on the bracing. He wanted to know the safe load we allowed on braces, and I told him 7500 lb. per sq.in. of section was the limit.

"The engineer thought that was a conservative figure and wanted to know why it was that we were so low

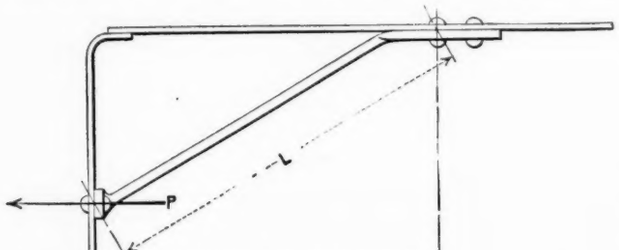


FIG. 1. DIAGONAL BRACE AND DIRECTION OF FORCE

on the stress allowed on braces. I thought that this was an opportunity to show off my knowledge of some of the features of boiler construction, so I told him that the low allowable stress was because the real stress on a diagonal brace was not the direct load on the head of the boiler due to the pressure, although this was the figure used in making the calculations. I drew him a sketch like this (Fig. 1), and I explained that if the load on the brace, due to the pressure, times the area supported by the brace was represented by the line P, it would indicate the direction in which the force acted, and that he could see that it was not in line with the brace. I pointed out that, in order to get the amount of stress produced by P in the direction of the length of the brace it would be necessary to multiply the force P by the fraction $\frac{L}{a}$, which he could see would result in a larger value than that represented by P. I also told him that the distribution of the load between the braces was not a certainty.

"This seemed to satisfy the engineer as to why the allowable stress for braces was so conservative, and I imagined that I had made quite an impression on him, but he went on to ask me some other questions, and that is when I found out that I needed more information on the subject. He wanted to know if the 7500 lb. allowed only applied to the round body of the brace, and I told him that it did unless the net section at the side of the rivet holes in the blade of the brace was of smaller area than the area of the body of the brace, in which case this net area would be used to figure the safe working stress that could be allowed.

"The next question was where he began to get me. He wanted to know how about the crowfoot end of the brace and how I figured the safe stress in that part. Well, I had to admit that I did not even figure that end of a brace, and I said that the makers of braces always designed that part to be able to resist any stress that the balance of the brace was capable of withstanding. The engineer then wanted to know if I ever found braces where the net section in the blade at the side of the rivet holes was smaller than the net section through the body of the brace, and I had to admit that I frequently found this to be the case. Then he wanted to know why a maker would design a brace weak in this respect, but always design the crowfoot to be amply strong. I could not answer that question, and I admitted that my reasoning was illogical.

"The engineer then wanted to know how I figured the rivets in the blade of a brace, and I had to own up that I never figured them, but I told him that such rivets were in shear and should be figured at $\frac{42{,}000}{5}$ or 8400 lb. per sq.in. of metal in shear. This seemed satisfactory, but he immediately wanted to know how the rivets in the crowfoot would be figured. I told him that they were under direct tensile stress and would be figured as having the same value as the material in the body of the brace. He then wanted to know why, if I considered these rivets were under direct tensile stress, it was not the actual stress. After the engineer made me admit that what he said was no doubt correct, he wanted to know why, when figuring the rivets through the crowfoot, I did not make an allowance for the fact that they were partly in shear, for he said that the load in the direction of the length of the brace would certainly place the rivets in the crowfoot partly in shear.

"Believe me, it was mortifying to have that engineer play with me in that way, and particularly with a subject which I should know more about than he did, for I had to admit that he had me stumped and that I really could not say whether the rivets in the foot of a diagonal brace were entirely in tension or whether they were partly in shear, and I am still in doubt."

"Well, Brown," said the Chief, "how much salary do you suppose that engineer is receiving?"

"I don't know," answered Brown. "What has that to do with it?"

"Because," said the Chief, "it is evident that he would make a bully boiler inspector unless he happens to have some bad habits that would disqualify him. Now, the argument that you have with that engineer has done you a world of good. It has set you thinking, not only on

this subject, but probably on others, so that you will be more inclined to analyze the different portions of boiler construction rather than take for granted that the way the other fellows are figuring things is all right and need not be questioned. You apparently got over the question of the stress in the body of the brace and also the question in connection with the need for getting the net section at the rivet holes in the blade of the brace in a very creditable manner. The question of how to figure the strength of a crowfoot is an important one, but I am afraid that I may not be able to give you a satisfactory solution of this problem.

"To start with, there is no need to discuss any but the solid crowfoot form of brace in connection with diagonal braces, for as you know, the pin-foot type has practically disappeared. There are four commonly used types of solid crowfoot braces: The welded type with the foot like this," said the Chief, drawing Fig. 2, "the weldless brace made of round bar steel, like the Scully (Fig. 3); the weldless plate brace, known as the Huston (Fig. 4); and the McGregor (Fig. 5). It will take a lot of figuring to tell if the feet of those braces are properly designed for the load they are supposed to carry. In the first place, the foot of a brace is in effect a beam loaded in the middle by the pull on the brace and with the ends supported by the rivets that attach it to

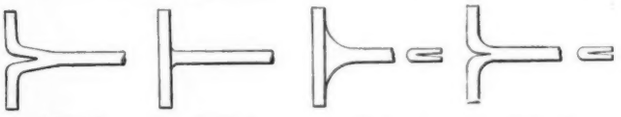


FIG. 2. WELDED BRACE — FIG. 3. WELDLESS BRACE — FIG. 4. WELDLESS PLATE BRACE — FIG. 5. ANOTHER TYPE

the boiler head; therefore, the distance between these rivets would be a factor in determining the strength of the foot. Of course, the size of the rivet heads would also be a big factor, because the span between supports is relatively small. It is not necessarily an undesirable thing to have the foot of a brace flexible, and the only thing to guard against is that the metal is not stressed too close to its elastic limit. Without making any figures on the problem, I think it would be safe, with the usual dimensions of such braces, if each side of the foot had as much metal in it as the body of the brace, or the net section that determined the strength of the brace, and without considering the metal removed by the rivet holes in the foot, and I guess you will find that most of the braces that are manufactured for sale have feet as heavy as this.

"There is no need to consider the net section of metal opposite the rivet holes in the foot of such braces, except to see that this section about equals that of the cross-section of the rivet, for there is very little stress produced on this section due to the pull on the brace. While the foot of the Scully brace might be figured as a beam, you can easily see that it would be almost impossible to make such calculations for the welded form or the pressed steel braces such as the Huston, and it would be practically impossible to get an accurate idea of the strength of the feet of such braces without making a test. Even after a carefully conducted series of tests, the improper fitting of the brace might throw all of the load on one of the feet and cause failure at a much lower load than would be expected from the results of test. This is one of those problems, Brown, where you have to depend almost entirely on experience to guide you, and I suppose that you are willing to admit that you do not often condemn a solid crowfoot brace on account of weakness in the foot.

"Now, as to the matter of rivets in the blade of a brace, your idea was practically correct—the rivets in the blade of a diagonal brace are almost altogether in shear, although there is a tendency to pull the head off the rivet next to the body of the brace, and on this rivet there is some tensile stress, but with the usual angle at which such braces are set, the rivets in the blade may be figured as being in simple shear."

"Well," said Brown, "I suppose that also answers the question in regard to the rivets in the foot, for they, too, are both in shear and tension."

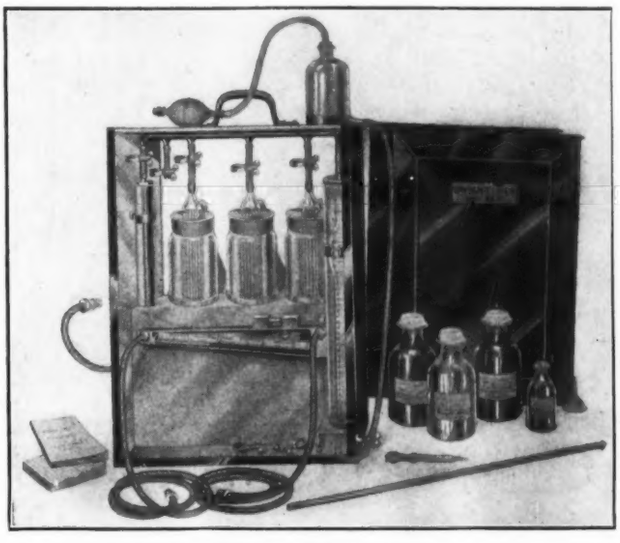
"Yes, Brown, they are to some extent in shear although the strain in a direction at right angles to their length must be slight, and if the cross-sectional area of rivets through the foot of a brace are made equal to the cross-sectional area of the body of the brace, they should be amply strong to resist any proper load placed on them due to pressure acting on the head."

"Well," said Brown, "I will not look at a crowfoot brace as such a simple thing in the future, and I am beginning to believe that every part of a boiler has a long explanation to go with it if we attempt to estimate just what stresses may be produced by the action of the steam pressure."

"Yes," answered the Chief, "and don't forget that in making calculations of the strength of such parts, in order to simplify the problem, we are practically always forced to neglect some of the factors that we know must exist, to say nothing of the many factors that we may be unaware of when making the calculations."

Dwight Boiler Furnace Kit

The outfit shown in the accompanying illustration and known as the Dwight furnace efficiency case has just been perfected. It comprises a flue-gas analysis apparatus of



DWIGHT BOILER-FURNACE KIT

rugged and practical design, a close-reading draft gage and a flue-gas thermometer, all fitted into a convenient portable case.

The flue-gas analysis apparatus has been designed for serviceability as well as accuracy. Where possible, more substantial material has been substituted for glass. The header connecting the filter, the measuring burette and the absorption pipettes is made of hard rubber. The filter is made of polished aluminum and designed so as to be easily refilled. The absorption pipettes are of simple two-part construction, the outer jar being of molded tough glass, which will stand considerable usage and, if broken, is cheap to renew. Ready-mixed chemicals and a quantity of nonevaporative colored draft-gage fluid are part of the equipment, as well as necessary rubber tubing, special connectors, test-report pad and an instruction manual on the operation of the apparatus and boiler testing in general. The manual is bound in loose-leaf form, so that special notes may be added from time to time.

Ample clearances are provided in all parts of the case, insuring, together with the features previously mentioned, accessibility and maximum strength.

The device is made by the Dwight Manufacturing Co., 12 and 14 South Jefferson St., Chicago, Ill.

Lap-Seam Boiler Again Indicted

State Inspector Harry E. Morton, of the Massachusetts Boiler Inspection Department, recently discovered a serious crack, Fig. 1, in the plates of a lap-seam boiler at East Boston and, as a result of an examination of seams beneath the setting, condemned the unit from further service. About one hundred persons had been working in

FIG. 1. CRACK IN BOILER AT EAST BOSTON

the immediate vicinity of the boiler. That an explosion had not occurred was indeed fortunate.

Mr. Morton said that the boiler was a 54-in. horizontal return-tubular type, seventeen years old and operated at 80 lb. The State House records show that it was made by Hodge and that it has been inspected annually by the department and certified. The boiler had double riveted seams, the plates being $\frac{5}{16}$ in. thick, and the rivets $\frac{3}{4}$ in. diameter. The boiler was operated beside another 54-in. unit with butt-strapped seams, the battery occupying a narrow area in a fire-room with brick partition walls, in the woodworking establishment of S. T. LeBaron. Steam is furnished to a reciprocating engine in an adjoining room, and heating service is also supplied from the plant.

From each boiler a smoke bonnet is connected with a brick flue carried along the top of the battery from front

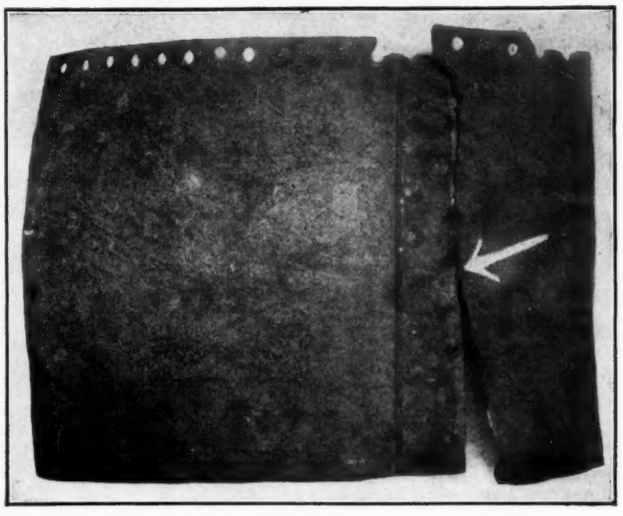


FIG. 2. PLATE OF THE WEYMOUTH BOILER

to rear and extending over two of the seams, making access for examination very inconvenient. The condemned boiler was shut down the night before Thanksgiving for inspection. In making the examination, Inspector Morton decided to make a more thorough investigation than required by law, the lap-seam type of boiler having been the type that exploded at the Grover shoe factory in Brockton, Mass., in 1906, at which time 58 persons were killed and 117 injured. The same type exploded at Lynn, Mass., shortly afterward, doing about $500,000 damage, and other disasters of this kind have occurred at Hubbardston and New Bedford, Mass., and more recently at Weymouth, Mass. [See editorial in *Power*, Nov. 23, 1915, in which the probability of legislation in Massachusetts providing for greater safeguarding of lap-seam boilers was touched upon as a result of the Weymouth explosion.—Editor]. The broken plate from the boiler at Weymouth is shown in Fig. 2.

When interviewed, Mr. Morton said that the crack which develops in lap-seam boilers is the cause of these disasters, and that if the treacherous seams are uncovered at the internal inspections, as should be required by law, it will aid the inspector to discover if a rupture has progressed far enough to start a leak. At East Boston Inspector Morton removed the brick setting above the seam nearest the engine-room wall and found evidences of leakage which apparently had been going on for years, unsuspected by any of the inspectors that had previously conducted the internal examinations of the boiler. The long-continued process of leaking had caused a deposit $\frac{3}{4}$ in. thick, 6 in. long and 4 in. maximum width on the outside of the boiler over the rivets. The deposit was scaly, but presented no evidence of rust or corrosion. It was knocked off in a single strip by an iron screw-driver, and the plate underneath was found to be red. Before testing the boiler with water pressure, Mr. Morton slotted

the plate between each pair of rivets, then applied hydrostatic pressure of 60 lb. per sq.in. The result was that water spurted out of the invisible crack in five distinct streams. Condemnation immediately followed.

Mr. Morton said that on Nov. 4 he petitioned the Massachusetts Board of Boiler Rules that it incorporate a provision in its regulations to the effect that when making annual inspections on cast-iron boilers, hydrostatic tests of from one and one-half to twice the working pressure shall be applied. At present the operating pressure is the limit of the test. This rule was in effect from May, 1908, to the present year. The petition was denied by the board, Mr. Morton states, without explanation, and the same action was taken upon a second petition by Inspector Morton to the effect that the uncovering of lap seams in annual inspections shall be required in examinations of boilers of this type. The latter is practicable, since a removable covering for boilers of all types has been devised by E. L. Storey, of the Hartford Steam Boiler Inspection and Insurance Co., and a covering designed after this plan is in successful service at the boiler plant of the Massachusetts State Prison, Charlestown.

In the Charlestown installation a battery of two 66-in. lap-seam boilers with double-riveted joints is equipped with six asbestos slabs, each covering one seam longitudinally, and reinforced by 5/8-in. iron rods brought out at the ends in the form of U-shaped handles to facilitate removal. Each slab is 5 ft. 5 in. long, 6 in. wide and 4 in. deep, and is bedded into a recess in the brick setting. The top of the asbestos slab is about 3½ in. below the surface of the adjacent brick setting, the lifting rings being about 5 in. high and 4 in. wide. In case of any leakage a discoloration of the asbestos will appear. In examining the boiler plates at the lap seams, the asbestos slab can be loosened easily by a small cutting tool and taken out of place with little or no delay. It can be replaced as easily.

At the 1916 session of the Massachusetts Legislature a bill will probably be introduced requiring the use of sectional removable coverings for the joints on lap-seam boilers.

Boiler Inspectors Deny Morton Charges

The following is a letter from the *Boston Post*:

To the Editor of the *Post*:

Sir—Our attention has been called to a statement made in your issue of Nov. 29, 1915, by State Inspector Harry E. Morton, of the boiler inspection department of the Massachusetts district police, that "inspectors employed in the boiler inspection department do their work carelessly and incompetently."

As no individual inspector is named, the inference appears to be that the State inspectors of boilers generally are careless and incompetent.

While it is our custom to avoid unnecessary controversy, it may be proper to state that all of the members of the boiler inspection department were appointed to that department upon a civil service basis, and that the character of their work received the following tribute in 1911 from the honorable justice who conducted the inquest after the Pittsfield boiler explosion:

"And I am unable to find that there was any fault whatsoever in the work of the inspection department relative to this boiler. On the other hand, since I have learned the facts in this case and the methods pursued by this department, I am inspired with confidence in its thoroughness and efficiency."

Our methods are increasingly careful and painstaking for the safeguarding of human life and property within this Commonwealth.

Yours respectfully,
George A. Luck,
Deputy Chief, Boiler Inspection Department.

Charles Ferguson, W. E. Simm, Willis A. Harlow, Sturgis C. Baxter, John B. Kearney, Franklin G. Wright, Henry Bushek, William W. Ramsay, Edward A. Mores, Benjamin S. Waterman, Herbert A. Sullivan, Percy B. Bragdon, Herbert E. Mitchell, J. W. Evans, Freeman H. Sanborn, Arthur F. Lovering, Franklin L. Forbush, George E. Richardson, Merrill W. Allen, Charles Skaglund, State boiler inspectors.

Motor Worm-Driven Pumps

There are many installations using the vacuum system of steam heating and carrying a pressure that is too low to satisfactorily operate steam pumps. In such cases the electrically operated vacuum and steam pumps have been

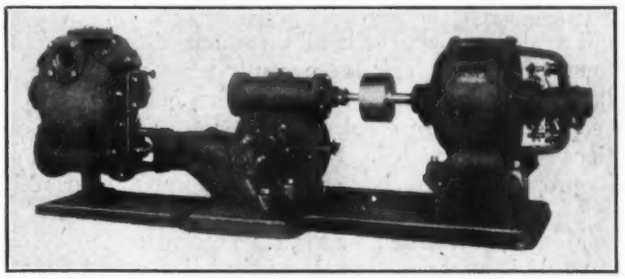


FIG. 1. VACUUM PUMP WITH MOTOR AND WORM DRIVE

used extensively, but there has been serious objection to them on account of the noise of the gearing.

The specifications for the new residence of Henry Ford, near Dearborn, Mich., were drawn with the idea of eliminating as far as possible the noise incident to the

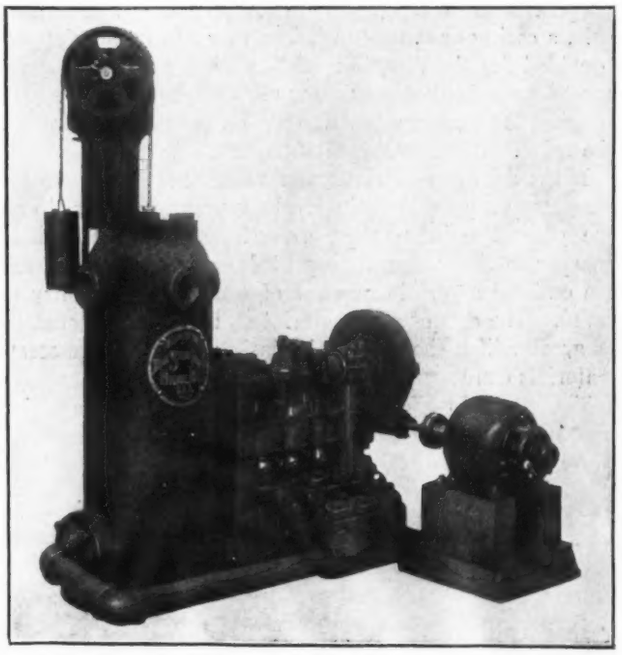


FIG. 2. PLUNGER PUMP WITH MOTOR AND WORM DRIVE

operation of the pumps on the heating system, and, as shown in Figs. 1 and 2, the pumps were arranged for direct connection to motors through worm drives, which, while not the best efficiency, still operate satisfactorily.

Fig. 1 shows the vacuum pump used in the steam heating system. It has an 8x7-in. single cylinder and runs at 34 r.p.m., driven through a flexible coupling by a 7½ hp. motor running 670 r.p.m. It serves 10,000 sq.ft. of radiating surface and discharges to the receiver shown with the feed pump, Fig. 2. This unit takes the discharge from the vacuum pump and all other returns, and discharges them to the boiler. The float in the receiver automatically starts and stops the motor, which drives the feed pump through a flexible coupling.

Casings for Machinery-Foundation Anchor Bolts*

By Bruce Page

SYNOPSIS—The function of casings, when to and when not to use them; materials that may be employed; and methods of maintaining them in position while pouring the foundation.

A casing for a machine-foundation anchor bolt is a tube, either of metal or wood, located concentrically around the anchor bolt. Its principal function is to permit a lateral movement in all directions of the top of the foundation bolt. This is frequently necessary because of inaccuracies in locating the bolts; also, holes in machine bedplates are often cored and inaccuracies in their locations may be expected. If the bolt or the hole is out of its proper place, the bolt can thus be sprung over readily so as to correct the inaccuracy; whereas if the bolt were solid in the foundation, that is, if no casing were provided, it would be necessary to enlarge the hole in the bedplate to compensate for the error. Obviously, it is an expensive and time-wasting procedure to enlarge holes in bedplates.

The second function of a casing is to permit the removal of the anchor bolt. Where this is desirable, it is necessary to provide a pocket under the anchor plate for the reception of the nut on the lower end of the bolt.

When to use and when not to use casings admits of no general answer. If the anchor bolts are to be removable, a casing or space must, in a concrete foundation, be provided for the reception of the bolt, or a casing space must be provided in a brick or stone foundation by so arranging the masonry that it forms a tubular hole around the bolt location, as shown in Fig. 1.

If the bolts are to be nonremovable, it is not absolutely necessary to provide casings. It appears, however, to be the general opinion that, everything considered, it is cheaper in the long run to provide casings. Where they are omitted a certain amount of concrete or masonry is saved. The cost of this material will usually be equal to or greater than the cost of the casing tube, because scrap materials can be utilized for the casing tubes.

The general practice seems to be to use casings for practically all machine and prime-mover anchor bolts. They are sometimes omitted from foundations for very small machines, because with these the probabilities of errors in bedplate holes or bolt location are small. Furthermore, such errors can be corrected at slight expense. Casings are not ordinarily used around the bolts of foundations for structural-steel columns, although they are used sometimes where the columns are large.

*Copyrighted.

The internal diameter of the casing is of little consequence, provided it is large enough; difficulties may result if it is too small. In the United States the general practice seems to be to make the internal diameter of the casing (*D*, Fig. 2) equal to the diameter of the bolt plus 2 in. Where the casing is square instead of round in section, each side of the square should equal the bolt diameter plus 2 in.

The length of the casing should ordinarily equal the distance from the top of the foundation down to the top of the anchor plate, as indicated by *L* in Fig. 2. However, where the anchor bolt is not removable and is long the casing may extend down only a distance equal to 25 or 30 diameters, as in Fig. 3, the former being the minimum, as this length is requisite to allow the top of the bolt to be moved readily.

There should be about one inch vertical space between the top of the foundation and the bottom of the machine bedplate after it is in its final position, for the accommodation of grout. The casings do not extend through the grout.

Where a casing space is provided in brick or stone foundations without providing a casing tube, the hole may extend from the top of the foundation down to the anchor plate, as in Fig. 1, or it may extend down into the foundation a distance of 25 or 30 diameters, as in Fig. 4. The latter cannot be used where the anchor bolt is to be removable.

Materials for Anchor-Bolt Casings

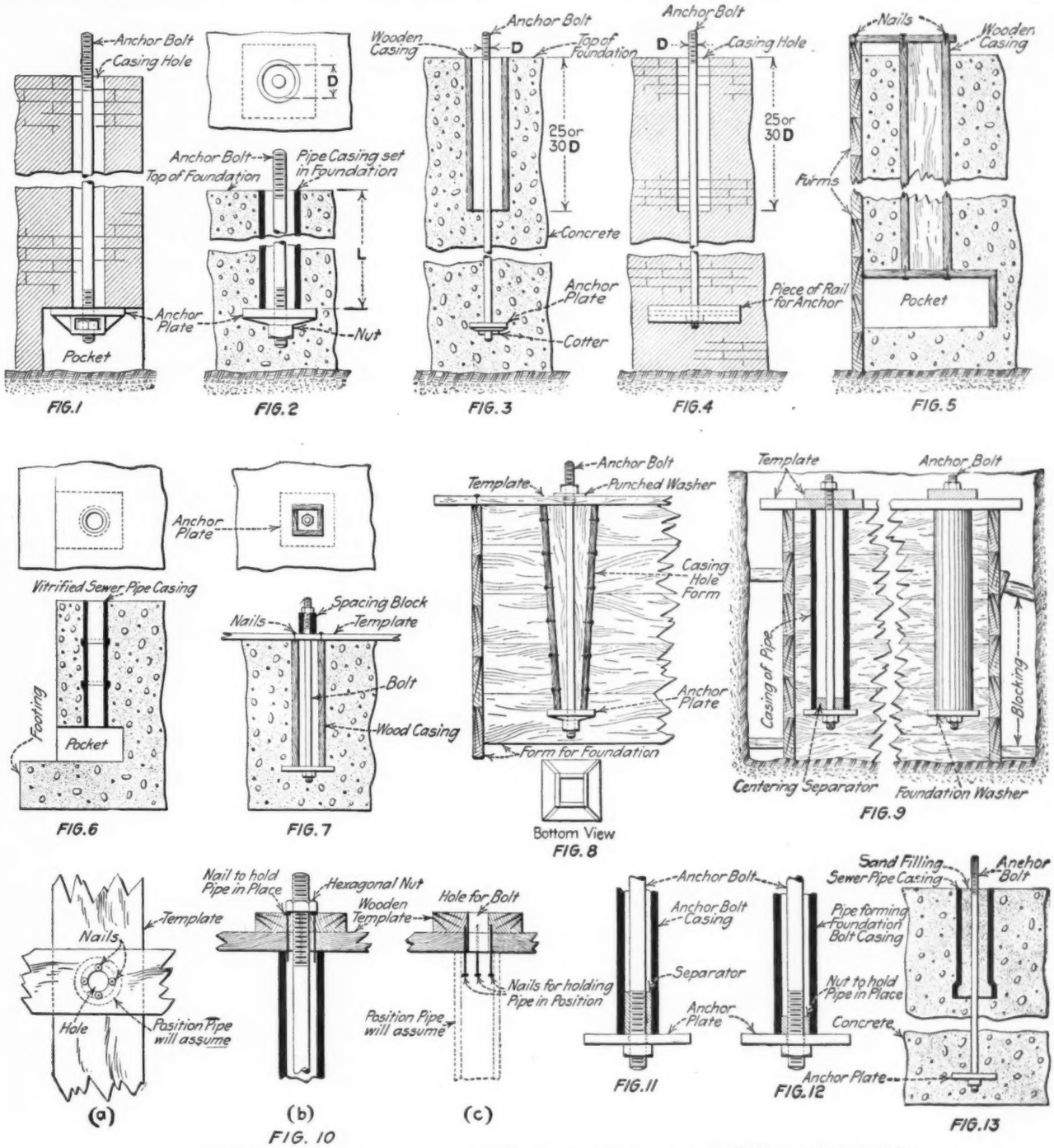
Almost any material that will provide sufficient stiffness to support the pressure may be used for casings. Fig. 2 shows a piece of wrought-iron pipe used as a casing, Fig. 5 indicates how casing tubes may be made of wood, while Fig. 6 illustrates a casing built up of lengths of sewer pipe. Casing tubes of metal are most frequently employed because generally they are the most readily obtained. Where the external diameter exceeds possibly 4 or 5 in., sheet iron becomes unsatisfactory because the tamping of the concrete may crush in the casing. Discarded boiler tubes or old wrought-iron pipe makes reliable casings for every condition. This results in the utilization of a great deal of old pipe that would otherwise go to the junk dealer.

Where the internal diameter required is relatively large and second-hand wrought-iron pipe cannot be secured, a casing built up of vitrified sewer pipe or of drain tile (see Figs. 6 and 13) will probably prove economical. In such cases it is frequently desirable to insert a wooden guide through the lengths of pipe to hold them in line

while the concrete is being poured or the masonry is being built around them.

Wooden box casings can be used as suggested in Figs. 5 and 7. They appear to satisfy all requirements, but in many cases there is a prejudice against the inclusion of wood in a machinery foundation. Sometimes the concrete foundation is poured with wood casings in place and then after the foundation is set, the casings are pried out, leaving only the hole. Wooden casings can be permitted to remain in a foundation or may be taken out. The one material objection to leaving them in is that the effective bearing area of the anchor plate against, the masonry is decreased; that is, if the casing is to remain the hole in the foundation will be greater by the thickness of the casing sides and the anchor plate will have to be somewhat larger in order to have bearing on an ample area of concrete. The bearing of the anchor plate against the lower end of the wood casing is obviously ineffective in resisting a tension on the anchor plate.

Wooden forms for casing holes, where the casing is to be removed, should be made about as indicated in Fig. 8. The taper from top to bottom permits the form to be extracted readily. Such forms, after being constructed but before being placed, should be allowed to remain in water until they absorb all that they will take up. Then they can be fastened in the form and the concrete poured. After the concrete sets and the casing forms dry and shrink, they can be pulled out easily.



DIFFERENT TYPES OF CASINGS AND TEMPLETS FOR FOUNDATION ANCHOR BOLTS

Methods of supporting casings from templates are shown in Figs. 5, 8 and 9. While a foundation is being constructed it is the usual practice to support the casings from the same template by which the anchor bolts are located and supported. Fig. 5 shows how the form for a casing hole and a pocket can be supported in a foundation being built of concrete. Fig. 9 indicates how the metal tubular casings for anchor bolts can be supported from a template in a form prepared for a concrete foundation. Fig. 7 indicates another method of holding a wood casing in a foundation under construction. A spacing block, such as therein shown, must be used where the tops of the anchor bolts extend different distances above the tops of the templates.

In supporting metal tubular casings in a foundation under construction, they must obviously be held in a perpendicular position. A bolt suspended within the casing will tend to hang perpendicularly because of its weight. Furthermore, the clamping action of the anchor plate on the casing when the nuts are tight tends to retain it in a vertical position. However, some difficulty may be encountered in keeping the casing concentric around the bolt unless suitable provisions are made. Sometimes, the friction between the upper face of the anchor plate and the casing and the lower face of the template and the casing is sufficient, when the bolts are tight, to retain the casing concentric to the anchor bolt. However, a safer procedure is to so restrain the casing, as indicated in Figs. 10, 11 and 12, that it must retain a concentric relation.

Centering and Supporting Casing by Nails

In Fig. 10 are shown two methods whereby the top end of a casing can be retained in its proper position by nails driven through the template. It is easier and better to drive the nails from the lower face as indicated at *c*, but sometimes the erector forgets to place them until after the casings and bolts are in position. Then, if the casings tend to get off center, nails can be driven in from the top of the template as shown at *b*. The lower end of the casing can be held in a concentric position around the anchor bolt, either by a pipe nipple, Fig. 11, a hollow cylinder of wood or a nut of suitable diameter dropped into the casing down from the bolt (see Fig. 12).

Sometimes, anchor plates are so cast that they have on their upper surfaces circular depressions whereby the casings automatically assume concentric positions around the anchor-bolt hole.

The centering of metal casing tubes resting on wooden pocket forms can be effected by making a circular recess in the top piece of the pocket form into which the metal tube will fit, or by driving into the top piece of the form four nails somewhat as shown at *a*, Fig. 10.

If nothing else is available, old newspapers crushed into wads and tamped around the anchor bolt within the casing can be used for the purpose of holding the latter in a concentric position.

In supporting wooden casings to templates, practically the same method as that indicated in Fig. 9 can be used where the foundation is not pocketed. Where pockets are employed, an arrangement similar to that suggested in Fig. 5 may be applied. This shows an instance where a casing is built in conjunction with the pocket and the roof form of the pocket supports the lower end of the casing, the upper end being held by a batten projecting from the foundation form. The top and side pieces of the pocket form are removed after the concrete has set. Fig. 7 shows how a wood casing can be supported from a template.

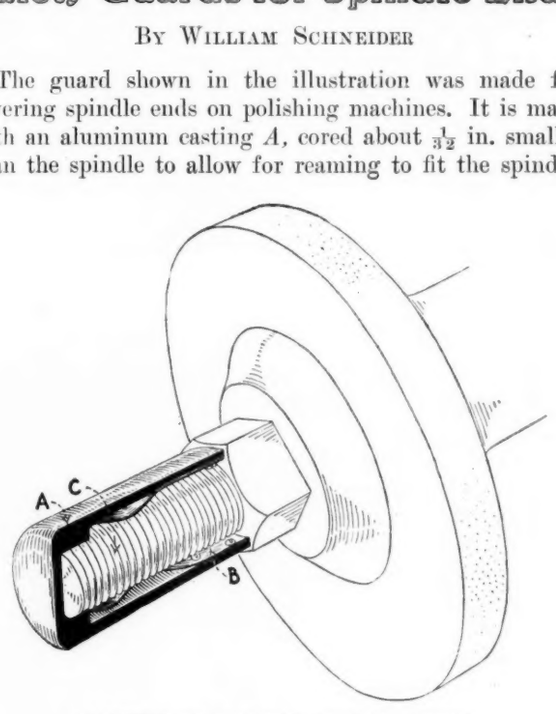
Whether or not anchor bolts should be grouted in casings presents some difference of opinion. Some erectors maintain that if a foundation is complete and the machine which it is to carry has been leveled and aligned and bolted to it, the casings around the bolts should be filled with grout to prevent any possibility of lateral displacement. The more prevalent opinion, however, is that they should not be filled with grout. This is also the writer's view of the matter. If a machine bedplate is properly grouted to the top of the foundation this layer of grout between the bottom of the machine bedplate and the foundation top will, of itself, prevent any lateral movement of the bedplate. Filling the casing with grout is then wholly unnecessary, and furthermore, it renders the removal of foundation bolts extremely difficult.

To prevent grout from entering a casing when the bedplate is being grouted in, the casing can be filled with fine sand, as shown in Fig. 13. Or, if sand is not available, the top can be stuffed full of paper, rags, waste, shavings, or any other material that will prevent the entrance of the grout and at the same time allow a movement of the top of the bolt. Where sand is used and it becomes necessary to remove one of the bolts, the sand will flow out of the hole in the anchor plate into the pocket, after the bolt has been taken out. Where a foundation is pocketed, but the pockets are closed, that is, inaccessible from the outside, sand should not be used, because it will flow down into the inaccessible pocket and fill it and prevent the reinsertion of an anchor bolt.

Safety Guards for Spindle Ends

By William Schneider

The guard shown in the illustration was made for covering spindle ends on polishing machines. It is made with an aluminum casting *A*, cored about $\frac{1}{32}$ in. smaller than the spindle to allow for reaming to fit the spindle.



SAFETY GUARD FOR SPINDLE ENDS

Two keyways *B* are cored $\frac{1}{4}$ in. wide by $\frac{5}{32}$ in. deep, about three-quarters of their length.

Two flat springs *C*, about $\frac{1}{32}$ in. thick, are bent and riveted to the sleeve. The sleeve is then assembled on the spindle as shown.

Record System for Office-Building Plant

SYNOPSIS—An outline of the record and cost-accounting system used in a large office building. It is not perfect in all respects, but may contain suggestions that will be of benefit to other plants of similar type.

To operate a plant efficiently and to know the cost of operation per unit of output, the first essential is a complete system of records. The second is an engineer who can interpret them properly and regulate the plant accordingly. It is important to have sufficient detail as a basis of judgment, so that the amount of data required depends upon the diversity of service rendered by the plant. The average office building requires heat, light, power for elevators and miscellaneous motors, or perhaps steam for the former, hot and cold water and, quite frequently, refrigerating service. The complication of the record system must therefore be greater than for plants of the same size serving other classes of buildings. A good example of what is needed is shown in the accompanying collection of report blanks and summaries. These forms and log sheets are used in one of the prominent office buildings of Chicago, which is 20 stories high and has cubic contents of 8,036,000 cu.ft. The plant has 750 hp. in boilers, 500 kw. in three generating units and three elevator pumps serving thirteen elevators. Continuous service is maintained, with three shifts, but naturally the load at night is light. For the year the current generated totals over 700,000 kw.-hr. Ten elevators are operated continuously during the day. In the heating season 68,000 sq.ft. of radiation must be supplied with exhaust and some live steam, and in addition there is the pumping of water for boiler feed and house service.

Power-Plant Log Sheets

The first three blanks are the initial sources from which operating costs are figured. The first is the engine-room log, giving the machines and the hours they are in service, the kilowatt output, the feed-water temperature and quantity, the house-heater temperature, etc. At the bottom space is reserved to call attention to any machine or apparatus out of service. The second is for the supplies given out during the three watches to the various departments. These are enumerated and there is a separate column in which supplies to repairmen are listed. In this way the supplies to the different departments are separated and the upkeep is also a separate item. The third is the boiler-room log, arranged to receive the weight of coal delivered to the boilers, the weight of ashes removed and the water-meter readings at the beginning and end of each watch.

For ready reference a summary of these daily reports is entered on report blank four, and at the end of the month the statement shown in the fifth report is filled out. At the top are the operating totals and below the supplies and repairs, which are entered under the proper departments as the bills are paid. As before, the items are separated and credited to the particular department or machine to which they apply. This subdivision is important, for if the power plant is saddled with all supplies and repairs for the building, the operating cost will be excessive. Then it is instructive to know just how much has been spent for furnace, boiler, engine, electrical or pump repairs. These items and others enumerated in the headings are given, and the totals for the month are placed at the foot of the statement.

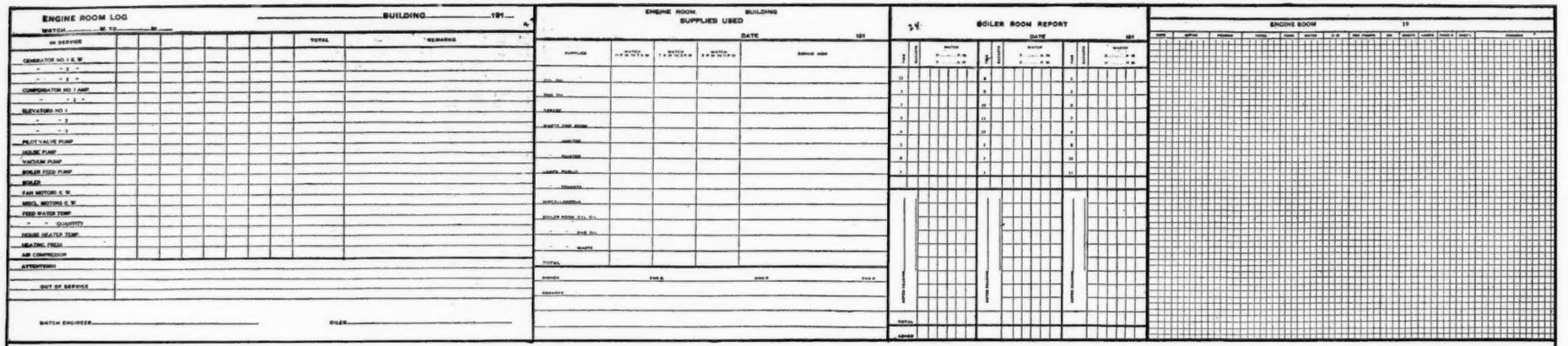
These monthly records are filed in a portfolio, and at the end of the year the report shown in the cost table is made. Here totals are given and a separation is made of the coal for the generating units, elevators and heating. The costs of water and ash removal are divided as shown. Without flow meters on the supply lines to the engines and elevator pumps and a meter on the returns of the heating, an accurate division is not practical, but an approximation was made in the following way: Tests were made on the engines and elevator pumps handling the average daily load. The water rates were determined, and knowing the hours of service, the steam to each department is calculated. The balance of the steam, which is determined by the difference between the foregoing totals and the metered feed to the boilers, is charged to heating and pumps for boiler feeding and house service. This only credits the live steam used for heating and does not take into account that much of the steam going to the other two departments should also be credited to heating during the time that the exhaust steam is used for this purpose. Without meters, however, this would be drawing the line rather fine, and in this case the division was not made.

Division of Coal and Labor

Knowing the steam to each department and the evaporation in the boilers, it was easy to divide the coal proportionally. A similar division of the labor should have been made. The figures for the year 1914 have been entered in this last report as they give relative values for the different departments. The first seven columns present the total operating expense outside of maintenance and fixed charges. Columns 8 to 12 give the electrical output, the proportion sold to tenants and that used for public light and power. In the succeeding columns the cost of coal, water and ash removal is divided as previously described, and in the final column the credits to the lighting plant are totaled. Deducting the total expense from the total credits leaves a balance of $23,039.14, which on the basis mentioned may be regarded as the gross profit at which the lighting plant is operated. To get the net profit it would be necessary to deduct the upkeep and overhead charges.

By adding the costs of coal, water, ash removal and a proportionate share of the labor, the cost of producing current will be found to be $271.90 + $5,988 + $300 + $3,342 = $9,901.90. Dividing this sum by the kilowatt-hours generated gives 1.38c. per kw.-hr. This is higher than it should be, as it will be remembered that the proper charge has not been made for heating.

In addition to this final tabulation an annual report is issued to the owner of the building. To the operat-



LOG FOR ENGINE ROOM, SUPPLIES USED, BOILER- AND ENGINE-ROOM REPORT AND MONTHLY STATEMENT SHEET

ELECTRIC-LIGHT PLANT COSTS

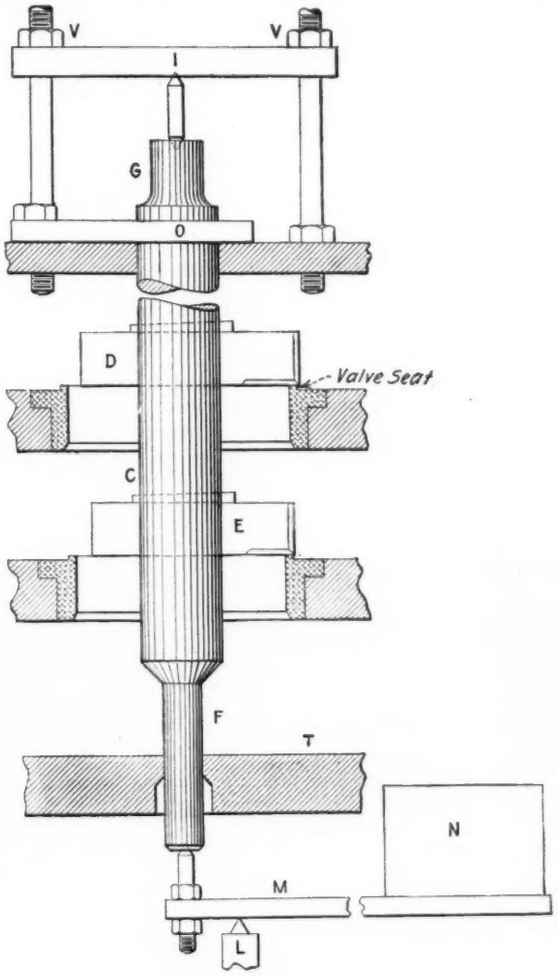
1914 • Month	1 Lamp Renewal	2 Total Water	3 Total Ashes	4 Labor	5 Oil, Waste Packing, Etc.	6 Total Coal	7 Total Expense	8 Kw. Generated	9 Kw. Sold	10 Public Light and Power	11 Coal Kw. Acct.	12 Coal Elev. Acct.	13 Coal, Heat, Etc.	14 Water Kw. Acct.	15 Water Elev. Acct.	16 Water to House	17 Ashes El. Etc.	18 Total Credit
Jan.....	$44.28	$248.85	$98.00	$790.00	$46.41	$1,724.00	$2,951.54	74,078	40,164	33,914	$621.00	$615.00	$488.00	$28.20	$27.20	$193.45	$62.00	$5,898.28
Feb.....	40.07	219.98	104.90	790.00	40.22	1,834.95	3,030.12	59,338	34,289	25,049	497.00	587.00	750 95	22.50	26.60	170.88	76.40	5,287.78
Mar.....	41.70	214.20	90.00	790.00	44.17	1,496.22	2,676.29	63,416	28,421	34,995	532.00	565.00	399.22	24.20	25.60	164.40	58.00	4,665.28
Apr.....	54.08	211.58	74.00	790.00	39.69	1,240.50	2,409.85	60,119	28,894	31,225	505.00	455.00	280.50	22.90	20.60	168.08	44.00	4,325 17
May.....	19.15	215.78	108.00	790.00	42.91	1,151.50	2,327.34	56,682	27,964	28,718	475.00	394.50	292.00	21.60	17.90	176.28	66.00	4,089.63
June.....	17.80	231.00	94.00	790.00	40.71	1,063.00	2,236.51	50,027	22,721	27,306	420.00	392.00	251.00	19.10	17.50	194.40	57.00	3,671.72
July.....	42.05	378.00	85.15	790.00	57.80	1,046.00	2,399.00	49,179	20,243	28,936	412.00	405.00	229.00	18.70	18.20	341.10	51.50	3,587.58
Aug.....	25.15	159.60	88.00	790.00	41.92	1,042.00	2,146.67	49,300	21,306	27,994	414.00	394.50	233.50	18.80	17.80	123.00	53.00	3,456.68
Sept.....	39.74	207.38	60.00	790.00	42.33	995.00	2,134.45	52,389	24,033	28,356	439.00	405.00	151.00	19.90	18.40	169.08	33.00	3,595.91
Oct.....	39.61	264.08	82.00	790.00	43.95	1,148.00	2,367.64	63,823	28,721	35,102	535.00	485.00	128.00	24.30	22.00	217.78	44.00	4,352.49
Nov.....	44.45	253.79	94.00	790.00	43.67	1,368.00	2,593.91	61,947	31,578	30,369	520.00	560.00	288.00	23 60	25.40	204.79	58.00	4,731.19
Dec.....	54.15	321.00	132.00	790.00	45.44	1,918.00	3,260.59	73,693	35,364	38,329	618.00	707.50	592.00	28.10	32.00	260.90	89.50	5,918.34
Total.....	$462.23	$2,925.24	$1,110.05	$9,480.00	$529.22	$16,027.17	$30,533.91	713,991	343,698	370,293	$5,988.00	$5,965.50	$4,083.17	$271.90	$269.20	$2,384.14	$692.40	$53,573.05

ing costs are added the upkeep and the fixed charges, such as interest on the investment, taxes, depreciation, rent for space occupied and the office expenses. The total is divided between the various departments so that the owner may know approximately what each service is costing, and these costs are reduced to a charge per square foot of floor space.

Facing Off Poppet-Valve Seats

By Lewis F. Lyne

The poppet-valve seats on a 20x42-in. engine had to be refaced. On consulting the shop where the engine was built, it was learned that they had no boring tools for doing this work. It is their custom to remove the steam chests, which are bolted to the cylinder, and chuck them in a lathe, and each chest would have to be set twice.



TOOL FOR FACING VALVE SEATS

In this instance the engine had to run every day and was shut down only 6 hr. in 24, hence it was necessary to face one valve at a time. It was said that boring bars were very unsatisfactory and that this work could not be done outside of the shop.

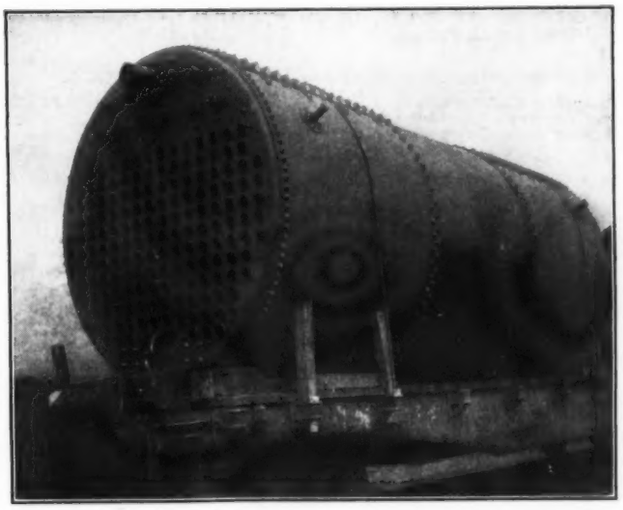
The valve seat was of composition brass set into the cast-iron partition of the steam chest. The seat, or face, was $\frac{1}{8}$ in. wide and projected about $\frac{1}{16}$ in. above, as shown. A boring bar *C*, having two $\frac{3}{8}$x$1\frac{1}{2}$-in. cutters *DE* did the work for both seats. One cutter only was used at a time, and each seat was faced separately. The lower end *F* was made to fit neatly into the hole through the stuffing-box *T*, while the upper end was secured by a steadyrest *O* made of 1x2-in. iron having in one end a hole fitting the boring bar. The other end had a hole to take one of the studs for holding the bonnet. It is imperative that there be no lost motion in the fit of these guides. The upper end of the bar was set very accurately in the center of hole in the casting, by the aid of inside calipers, as is customary. The top end *G* was turned to 1 in. in diameter, so that it might be operated with a Stillson wrench. The clamp *I* was slipped over the top ends of the studs inserted in two of the bonnet stud holes.

The "little joker," without which it would have been impossible to have faced off these seats true, is the counter-pressure upon the lower end of bar, which must be of considerable magnitude. This counterforce was introduced in the form of the lever *M*, with a center point and a fulcrum *L*. By the application of the weight *N* the cutter is kept in position, whether in contact with the seat or not, and when the cutter is brought into contact by screwing down the nuts *V*, it will take off the metal wherever necessary to produce a true surface. It required about a half-hour to face the two seats on each valve, and the work was entirely satisfactory.

Large Return-Tubular Boiler

In the Mar. 30 issue is illustrated a boiler 9 ft. diameter by 18 ft. long, designed for a working pressure of 125 lb.

A larger return-tubular boiler than this is herewith illustrated. It is one of four made by the E. Keeler Co.



RETURN-TUBULAR BOILER WEIGHING ABOUT 48,500 LB.

and shipped to Albuquerque, N. M., in June, 1913. These units have developed as high as 570 hp. each. The illustration shows one of the boilers on a freight car. It is 9 ft. diameter and 20 ft. long, and was accepted by a prominent insurance company for a safe working pressure of 180 lb. The weight of each bare boiler was about 48,500 lb., or 24¼ tons.

Velocity of Water in a Pipe in feet for a given quantity discharged equals the cubic feet delivered multiplied by 144 and divided by the area of the pipe $= \frac{\text{cu.ft.} \times 144}{\text{area of pipe}}$.

Cost of a 2,900-Kw. Plant

To show the Massachusetts Public Service Commission the cost of its entire system, the Bay State Street Railway Co. of Boston had an inventory taken of its property by Sloan, Huddle, Feustel & Freeman, of Madison, Wis. These engineers went over the road with a fine-toothed comb, listed every item of investment on the company's books, examined every foot of track, noted the details of every span of wire, counted every pole, measured every building, hunted down the cost of every piece of apparatus, and by consultation with department heads and personal examination of every available voucher, obtained as close an idea of the outlay as eighteen months' work by an average staff of fifty experts and assistants could accomplish. The results of this inventory, which shows the cost of the property in detail as of Nov. 1, 1914, are filed in ten volumes at the office of the commission.

The cost in detail of the various power stations of the company in Massachusetts is included in this exhibit, and some of the figures are of particular interest to the engineer, especially if he is likely to be called upon to make an estimate of construction costs. The abridged costs given are those of a 2,900-kw. steam plant owned and operated by the company at East Woburn, and the data shown represent, as nearly as was possible to procure them, the actual money expended on the installation from its original construction about a dozen years ago down to last year. The figures do not necessarily mean that these detailed costs would apply in building another station of this size somewhere else today, but they at least furnish a basis for comparison and form a starting point for similar analyses by engineers to whom cost data are accessible. Certain allowances for fixed charges are included to arrive at the true plant investment value.

EAST WOBURN STATION, CAPACITY 2,900 KW.

Land for station site		$4,200
Engineering, interest, contingencies, taxes and organization expenses during construction, 8 per cent.		336
		$4,536
Power house building, about 100x130 ft.; frame structure, concrete foundation, brick fire wall separating boiler from engine room; roof, timber covered with tar and gravel. Plant in good condition at present.		
Excavation	$1,481	
Trenching	295	
Concrete foundation and walls, 401 cu.yd. at $7	2,807	
Concrete conduit, 0.4 cu.yd. at $8	3	
Concrete piers, 10 cu.yd. at $8	80	
Concrete floor, plain, 6 in. thick, 6,293 sq.ft. at 20c.	1,259	
Concrete floor, reinforced, 5 in. thick, 5,003 sq.ft. at 45c.	2,251	
Concrete steps and curbs, 7.9 cu.yd. at $8	63	
Concrete roof, 3.5 in., reinforced, 259 sq.ft. at 35c.	91	
Concrete trenching, 5.5 cu.yd. at $7	38	
Brick wall, 89 M. at $22	1,958	
Brick piers, 2.7 M. at $24	65	
Timber	5,170	
Roofing tar and gravel, 13,970 sq.ft. at 6c.	838	
Millwork	1,557	
Steel (including 28,899 lb. flues at 9c.)	4,922	
Cast iron, 18,150 lb. at 3c.	544	
Brass railing, 522 lb. at 30c.	157	
Sheet metal	33	
Plumbing	178	
Electric lighting	414	
Painting, oil, 1,900 sq.yd. at 18c.	342	
Painting, cold water, 1,369 sq.yd. at 12c.	164	
Plaster, 600 sq.yd. at 28c.	168	
Exhaust, injection and discharge, etc.	3,953	
Water pipe and hangers	2,751	
	$31,582	
Coal tracks and scale in boiler room	1,476	
Tank on power house	163	
Fence, 686 ft. long	744	
Hotwell	260	
Cold well	2,295	
Dam	542	
Pondage	1,980	
Trough	81	
Miscellaneous supports	236	
	$39,359	
Engineering, interest, insurance and contingencies, 11 per cent.		4,329
Taxes and organization, 3.5 per cent.		1,377
		$45,065
Chimney (built in 1912; Custodis, 175 ft. high; diameter at top, 9 ft.).		
Excavation, 139 cu.yd. at $1	$139	
Concrete, 124 cu.yd. at $7	868	
Brick, common, 110 M. at $20	2,200	
Brick, radial, 5,920 cu.ft. at 40c.	2,368	
Brick, radial fire, 242 cu.ft. at 75c.	181	
Lightning rod, 175 ft.	130	
Cast-iron door	10	
Steel lintels, 814 lb. at 4c.	33	
Iron steps	100	
	$6,029	
Fixed charges as above, 14.5 per cent.	874	
		6,903
Coal trestle		5,449
Store shed		320
Oil house		248
Hydrant houses		302
Water softener building		1,180
Total structures cost		$59,467
Station equipment—		
Six 400-hp. B. & W. boilers and superheaters (water-tube), at $14.35 per boiler h.p.		$34,428
Foundations for above		1,391
One Spencer damper regulator		95
One Simmance-Abady precision CO_2 recorder		300
Two G. E. indicating steam-flow meters		144
Four 1.5-ton fuel charging cars		400
One 5x8-in. Deane triplex boiler-feed pump		462
Foundation for above		34
One 25-hp. New England direct-current motor		365
Foundation for above		23
One 10x6x12-in. Dean duplex boiler-feed pump		325
Foundation for above		53
One 2.5 four-stage Alberger-Terry boiler-feed pump		975
Foundation for above		29
One 7.5x10.25x10-in. Worthington vertical duplex boiler-feed pump		375
Foundation for above		18
One 4x6-in. Deane triplex boiler-feed pump		266
Foundation for above		8
One 7.5-hp. G. E. direct-current motor		225
One 4.5x2.75x4-in. Worthington duplex pump		81
One 5.25x3.5x5-in. Deane duplex pump and receiver		79
Two 30x96-in. Wainwright tubular closed heaters		1,120
One 30x90-in. Wainwright tubular closed heater		560
One 34x108-in. Wainwright tubular closed heater		950
Foundation for above		26
One 34x96-in. "National" closed coil heater		845
Foundation for above		4
One Sturtevant flue-gas economizer		5,174
Foundation for above		264
One 2,100-hp. "We-Fu-Go" water purifier		3,750
One 2-in. recording and indicating venturi meter		500
One 18x10x12-in. Platt duplex underwriters fire pump		890
Foundation for above		23
Station piping (approximately $10 per kilowatt)		29,656
Pipe covering		1,418
One 30.5x48x48-in. Penn. Corliss cross-compound engine		22,387
Foundation for above		4,041
Two 28x52x48-in. Penn. Corliss cross-compound engines		44,760
Foundations for above engines (2)		12,721
One 28x60x60-in. Cooper-Corliss cross-compound engine		25,600
Foundation for above		5,254
One 13.5x24x24-in. Smith-Vaile jet condenser		1,093
Foundation for above		42
Two 14x26x24-in. Deane uniplex jet condensers		2,690
Foundations for above		79
One Wheeler jet condenser and auxiliaries		5,115
Foundation for above		92
One 50-hp. G. E. direct-current motor		725
Foundation for above		20
One 6-in. Lawrence centrifugal pump and motor		602
One 12-in. Lawrence centrifugal pump		248
One 9.5-in. Westinghouse locomotive-type air compressor		162
One 2.25x3-in. Blake triplex oil pump		78
One 2-hp. New England direct-current motor		85
One 2x1.25x2.75-in. Blake duplex oil pump		30
One White Star oil filter		660
One oil- and waste-saving machine		160
Miscellaneous tanks, filters, etc.		366
Three G. E. 850-kw., engine-type, 550-volt, multipolar, direct-current generators		36,535
One G. E. engine-type, 550-volt, multipolar, interpole, direct-current generator		17,260
Switchboards and wiring		8,010
Miscellaneous equipment and tools		612
		$274,683
Engineering, interest, insurance and contingencies, 10.5 per cent.		28,842
Taxes and organization, 3.5 per cent.		9,614
Total equipment		$313,139

SUMMARY OF PLANT COST

Land	$4,536
Building and structures	45,065
Chimney	6,903
Coal trestle, shed, etc.	7,499
Equipment	313,139
Grand total	$377,142
	or $130.05 per kw.

Editorials

The Year's Review

One of the notable features of the year was the Panama-Pacific Exposition, which, despite the disturbance due to the war, which caused over 60 per cent. of its space reservations to be canceled in October before the opening, was carried out to a successful issue. Although commemorative of a great engineering achievement and administered by a president who is an engineer, the exposition was not strong in engineering, especially mechanical-engineering exhibits, and the purchase of its supply of energy made the power exhibit pitiably lacking.

The congresses held in connection with the exposition brought out many interesting papers from eminent foreign, as well as domestic, authorities and were well attended.

Large Power-Plant Equipment

Size always lends interest to a machine or apparatus of any kind, and when it is the largest in its particular field it is at least worthy of mention. Looking back over the files for the year just closed, the first mammoth installation to attract attention is a duplex inclined cross-compound hoisting engine reported to be the largest of its kind in the world. The two high-pressure cylinders are 28 in. in diameter, the two low-pressure 52 in. and the stroke 42 in. The hoist, which was ordered by the Homestake Mining Co. and built by the Nordberg Manufacturing Co., lifts 12,000 lb. net of ore per trip from a depth of 3,200 ft., the total pull on the rope being estimated at 41,900 lb.

Another giant, but in a different field, is the C. H. Wheeler jet condenser installed in the Westport power plant of the Consolidated Gas, Electric Light and Power Co., in Baltimore. The condenser serves a 15,000-kw. turbine and is designed to care for 200,000 lb. of steam per hour at an absolute pressure of 1.5 in. and with 25,000 gal. of 70-deg. injection water. In surface condensers the largest to report for the past year is the equipment to be supplied by the Wheeler Condenser and Engineering Co. for the 35,000-kv.-a. turbo-generator ordered for the Northwest station of the Commonwealth Edison Co., of Chicago. It has 50,000 sq.ft. of surface which at rating will condense 360,000 lb. of steam per hour and a maximum of 400,000 lb., or 8 lb. of steam per square foot of surface per hour. An average vacuum of 29 in. is expected, and under normal conditions 50,000 gal. of water per min. will flow through the condenser.

Two 12,000-hp. electric motors were supplied by the Westinghouse Electric and Manufacturing Co. for reversing blooming mills, these being the largest electric-motor-driven steel mills in existence.

The largest single-tandem gas blowing engine constructed to date in this country was built by the Mesta Machine Co. for the Pennsylvania Steel Co.'s plant at Steelton, Penn. It has gas cylinders 46 in. in diameter, air cylinders 84 in. and a stroke of 60 in. The speed ranges from 45 to 85 r.p.m.

The first return-tubular boiler 108 in. in diameter recorded under the laws of the Commonwealth of Massachusetts was built by the D. M. Dillon Steam Boiler Works for a safe working pressure of 125 lb. The boiler has 200 four-inch tubes 18 ft. long, and the steel shell plates and the heads have a thickness of $\frac{5}{8}$ in. Complete with all castings and fittings, it weighs 84,440 lb.

An unusually large fan of the turbo-conoidal high-speed type for cooling air-blast transformers was installed at the Blue Island power house of the Public Service Co. of Northern Illinois, by the Buffalo Forge Co. It handles 40,000 cu.ft. of air per min. at 70 deg. and 29.92 in. barometer, with a static increase in pressure of 2.6 in. of water.

The Ox-Bow hydro-electric plant on the Snake River, in Oregon, has the distinction of possessing the most powerful chain drive in the world; it is rated at 5,000 hp. The drive connects two waterwheel shafts with a single generator shaft, each of the two pairs of sprockets carrying four Morse silent driving chains 31.67 ft. long and 21 in. wide and weighing about 2,800 lb. each.

The past year has seen the completion of the two great coal-handling plants on the Panama Canal—one at Christobal having a storage capacity of 400,000 tons, and the other at Balboa with a storage capacity one-half as great. In the same order the plants will be capable of handling 2,000 and 1,000 tons of coal per hour.

Notable Generating Stations

Of the various steam-power plants put into commission during the year, the installation at Connors Creek must be regarded as the last word in power-house design. The outstanding feature is a special house-service system consisting of a turbo-generator served by a barometric condenser, the latter acting as an open feed-water heater for the plant. The back pressure imposed upon the turbine regulates the feed-water temperature, affording great flexibility in maintaining the station heat balance. Stray heat units, such as are radiated from the steam piping, turbines and generators and allowed to escape in the average plant, are recovered at Connors Creek and returned to the boiler furnaces in the form of preheated air. The coal-handling system and the piping have interesting features. The condensers are of improved design, the horizontal baffling having been removed and the air boxes increased in size, this resulting in a reduction in drop through the condenser and a gain of from 0.1 to 0.5 in. of mercury under the wheel. The makeup water is distilled, and on the electrical end the generators are tied solidly to the transformers, no reactances being used as protection against short-circuits.

Other plants representing the best modern practice and employing large units that have recently been put into service are the Essex station of the Public Service Electric Co. of New Jersey, the Christian St. station of the Philadelphia Electric Co. and the new municipal station at Regina, Canada, recently described in these columns.

In steam-turbine development the most notable feature is the continued and increasing use of larger units. Several machines of 30,000-kw. capacity are in service, as is also the 35,000-kw. unit of the Philadelphia Electric Co.; a 40,000-kv.-a. machine has been ordered by the Duquesne Light Co., of Pittsburgh; the Detroit Edison Co. is contemplating 45,000-kw. units at a new station to be added to the Delray group; and rumor has it that a 50,000-kw. unit is soon to be built in this country. The economy of these monster turbines and even of smaller machines is increasing so that the water rates are lower than ever before, gains of 10 to 20 per cent. being recorded over turbines built a few years ago. There has been a tendency to open up the exhaust end of the turbine to give unrestricted passage to the immense volumes of steam at the lower vacua. Speeds are increasing even in the larger units, and a great deal of attention is being given to reduction gearing. Direct-current units, in sizes suitable for exciters and even large machines, are now coupled to high-speed turbines through reduction gears. These gears permit speeds for both machines favorable to the highest economy in construction and operation. For the same reason gears are also employed with small 25-cycle alternating-current generators. In a recent issue a description was given of a 100-kw. direct-current machine driven directly by a steam turbine at 2,200 r.p.m. For a generator of this type the speed is high, and to insure regulation with a combination elevator and lighting load special precautions were taken in the design.

An interesting innovation is the invasion of the rolling-mill field by the steam turbine. The Carpenter Steel Co., of Reading, Penn., has installed a low-pressure De Laval nine-stage turbine to drive two stands of 18-in. three-high mills. The speed of the turbine is 5,000 r.p.m., and by means of double helical involute gears this is reduced, first to 600 and then to 100 r.p.m. It is the first instance in the United States and the second in the world where a low-pressure turbine fitted with reduction gears has been adapted to a rolling mill.

Improved Condenser Design

With the development of the turbine every effort is being made to improve the condenser so that it will handle economically with minimum drop the great volumes of steam. Restricted passages are being eliminated and baffles redesigned, or removed as at Connors Creek, to reduce the pressure drop through the condenser. With the improved air pumps in use, the importance of maintaining uniform steam velocities is being realized and provided for by large areas at the inlet and a gradual tapering to nothing toward the air offtake. One of the most notable condensing equipments is that previously mentioned as under construction for the Northwest station in Chicago.

A two-stage condenser has been proposed, in which part of the steam is to be condensed in the first stage at a vacuum of, say, 29 in., the balance of the steam passing through the final stage of the turbine to the second stage of the condenser under a vacuum of 29½ in. Worthwhile gains are computed over the standard condenser, and extremely high vacuums are possible without undue increase in area of the final stages of the turbine.

An electrical-resistance method for determining surface-condenser leakage has been developed during the past year. Samples of distilled water were placed in a vessel containing two electrodes. By passing an electric current through the water, its resistance at a certain temperature was measured. Results from other tests on mixtures of condensation and circulating water gave a curve to which the resistance of any particular sample could be referred and the proportion of circulating water contained be closely determined. These samples are drawn under operating conditions, and the results obtained have been surprisingly accurate.

Steam, Gas and Oil Engines

Although the field of the large steam engine is rapidly narrowing, there are still numerous applications for the smaller machine. The uniflow engine, particularly for condensing service, still demands consideration and engines of improved poppet-valve type have shown remarkable economies for small units. The increasing use of plate valves for high-speed air compressors is an interesting development of the year.

The situation in the gas-engine and producer field has changed but little from that of a year ago. In the natural-gas sections and for small isolated plants such as pumping stations, the gas engine in medium and small units may be said to be holding its own, but is not gaining to any perceptible extent. Also, a few large gas blowing engines have been built during the year.

The stationary Diesel engine in sizes under 500 hp. continues to gain a footing—slowly perhaps, but with encouraging prospects—the four-stroke-cycle type predominating. The medium-compression type also shows increasing sales.

Steam Boilers and Explosions

Within the last year there has been much activity in the boiler room. Operating conditions are being improved, and strenuous efforts are being made to increase the economy. It is realized as never before that here is the place to make large savings. Stoker designs show marked improvement. Furnaces provide for proper mixing of the gases and are sufficiently large to permit complete combustion. There has been a decided impetus in providing instruments to show the fireman what he is doing at all times and to record continuously operating conditions. Large boilers are becoming more common, probably owing to the larger generating units. Higher economy, lower operating cost and less expense for settings and fixtures have vindicated their use. With the increase in grate surface and better conditions for complete combustion, there has been a decided tendency toward higher capacities from a given heating surface. The old allowance of 10 sq.ft. of boiler-heating surface per horsepower is becoming obsolete, and the horsepower of boiler per kilowatt of generating capacity has been reduced from an equality at one time to a ratio of 1 to 5 for normal conditions in the larger plants. Steel casings, which reduce radiation when properly insulated and prevent air infiltration through the setting, have been an important factor in improving the economy and are now included as an essential part of a modern setting.

Following the trend of the last few years, pressures tend upward. The latest report comes from the Public Service Co. of Northern Illinois, which is to install boilers designed for 350 lb. pressure and 200 deg. superheat. This is a tremendous jump over past practice, and the details as soon as they have been worked out will be of great interest

Owing to these higher pressures and superheats, the flue gases must leave the boiler at higher temperatures, and with less exhaust steam to heat the feed water because of the increasing use of motors to drive auxiliaries, the economizer is finding favor in several large plants, although one put into commission during the year omitted economizers because it was felt that cast iron was not a satisfactory material for the high pressures employed and that economizers of a more suitable material would soon be available.

During the year ending June 30 there occurred 371 boiler failures. The number reported killed was 127 and injured 314; reports of property loss, 107, estimated at $155,325, making an average of about $1,450.

Of the strictly power-plant failures 51 were tube failures; 12 cast-iron header failures; 23 blowoff-pipe failures and 10 caused by over-pressure.

Electricity and Refrigeration

The last year has seen few marked advances in electricity, with the possible exception of the transcontinental telephone, although there has been a steady and healthy growth of the electrical industry. The deadlock in legislation affecting hydro-electric development is responsible for practically nothing new in that line. Several large steam stations have recently been put in service or are nearing completion, and the sizes of generators have increased to keep pace with the increased turbine capacities. Many improvements have been made in small apparatus and meters, and the use of electricity for domestic appliances has increased, largely the result of the "Electrical Prosperity Campaign" which was pushed throughout the country.

Nothing of unusual interest has happened in the refrigeration field. The building of raw-water ice plants goes on apace, and the application of the small so-called automatic refrigerating machine continues to increase; consequently the development work on this type of machine is hastened. Some interesting applications of these small machines have been made in the field service of the armies in Europe. A laundry is using refrigeration for drying purposes and pronounces it a success.

The year has seen an awakening here and abroad of the desire to determine the causes of, and the means to prevent, explosions in ammonia refrigeration plants. Considerable work is being done by the Bureau of Standards and by various men working independently, to obtain more accurate knowledge of the physical properties of ammonia.

Marine Tendencies

In marine practice there has been a noticeable increase in the use of steam turbines, especially in connection with reduction gearing. This type of drive has proved successful on small ships running at moderate speeds. As the speed of the vessel increases, the gear problem becomes more difficult. The war has retarded progress to some extent, and its effect has been felt especially in the commercial development of the Diesel engine for marine work. Nevertheless a few vessels have been fitted with Diesel engines during the year, Lloyd's report classing a total of 38 vessels having this type of machinery. Noteworthy in this connection is the completion by the Government of one of the 2,500-hp. six-cylinder Diesel engines for the fuel ship "Maumee," the largest Diesels yet built in this country.

Electric propulsion advanced a step with the signing of the contract for the battleship "California."

Interesting news from the marine field was the creation of a United States Naval Consulting Board and the appointment on this board of 23 of the most prominent engineers of the country. Their experience and service, which will be at the command of the Government at all times, should result in a great deal of good.

Coal and Smoke Prevention

The proposed revision by mine operators of the present standard sizes of anthracite will be of interest to those power plants burning this fuel. The proposition to combine chestnut and pea in one size and to mix buckwheat Nos. 2 and 3 to form "steam coal," may result in a higher price per ton to the consumer and cause considerable remodeling of grates. Apparently whatever advantage may result from the change will be on the side of the mine operator.

In smoke reduction Pittsburgh has some wonderful results to report. During the first six months of the year the number of smoky days was 45 per cent. less than during the same period in 1912, and with the increased activity of the mills during May and June the drop in the number of smoky days was over 50 per cent. Besides, the smoky periods of the days reported were shorter than formerly, so that the hours of smoke per month would indicate a still greater reduction. In the number of complaints of objectionable smoke received by the railways from the Bureau of Smoke Regulation a reduction of 78 per cent. is reported for the first six months of 1915, as compared with the last six months of 1914. In the smoke ordinance new features not found in the ordinances of any other city appear. The smoke limits were changed from eight minutes in one hour for all stacks to one minute in any period of eight minutes for locomotives and steamboats, and two minutes in any period of fifteen minutes for all stationary stacks.

Continued success in the abatement of smoke is the word from Massachusetts. Reports from other states show that the cities that have been carrying on active campaigns are apparently doing the best they can under limited appropriations. Chicago, the pioneer in the movement, is resting on its laurels—not from lack of funds, but from appointments made with more regard to politics than to qualifications or achievements.

In British circles the investigation into the damage by smoke and means for reducing factory and domestic smoke is being continued. It may be remembered that the City of Manchester created in 1913 an Air Pollution Advisory Board. Other cities have followed suit, and in September last the British Association for the Advancement of Science, as a result of a special session on "Smoke and Its Prevention," appointed a British Association committee to coördinate and encourage the work of the various town committees.

Engineering Societies

A noteworthy incident in the history of the engineering profession was the inauguration of the Engineering Foundation last January. An initial gift of $200,000 was donated by Ambrose Swasey, "to be devoted to the advancement of the engineering arts and sciences in all their branches, to the greatest good of the engineering profession and to the benefit of mankind." The administration

of this fund is to be intrusted to a board of eleven members, two each from the four leading engineering societies of the country, two chosen at large and the president of the United Engineering Society, the holding corporation of the Engineering Societies' Building, in New York City.

The schedule of flanged fittings as finally adopted went into effect the first of the year, and on Feb. 13 the American Society of Mechanical Engineers approved the proposed boiler code finally submitted for that purpose. It has been characterized as the greatest single piece of work that the society has ever done and should reflect lasting credit on the committee and the society as a whole. Already a number of states have adopted the code and more are likely to follow suit. The sooner its influence is felt in every state in the Union the better, for the code is sure to result in decreased loss of life and property from boiler accidents.

License and Inspection Laws

Out of the 49 states in the Union 34 have no state laws and no proposed legislation for licensing stationary engineers. Nine other states had laws pending in 1915, but for one reason or another the bills were lost. There is consequently no progress to report, although a great deal of activity was displayed. The lack of results is to be regretted in a matter of such great importance. Consistent and earnest endeavor, however, should avail in the end, and in the year to come let us hope for better returns. The model boiler-inspection and engineers' license law drawn up by a special committee appointed at the joint meeting of the American Boiler Manufacturers' Association and the International Association of Tubular Boiler Manufacturers, at Pittsburgh, for the use of committees attempting to obtain such legislation, should be of inestimable value. The model law, with its reference notes giving specific information concerning the number of inspectors, inspections, examinations, etc., together with a digest of existing laws, should be an excellent guide and help toward securing that desirable condition of uniform state laws.

During the year Massachusetts amended its state license law and in addition passed a bill establishing a board of examiners to license electricians. With the repeal of certain sections of the general statutes, Connecticut has a new boiler-inspection law. Montana passed a law requiring all persons operating electric and air hoisting engines, when used in lowering or hoisting men, except in elevators in buildings, and when of more than 25 hp., to obtain a license after proof of proper qualifications. It remained for Colorado to allow its boiler-inspection department to die a natural death by not providing sufficient funds. Under the plea of economy it is proposed to combine this department with that of factory inspection. Whether this arrangement will properly safeguard the public against the danger of boiler explosions will depend on how carefully the factory inspectors are chosen.

The Honor Roll for 1915

As was the case a year ago, the honor roll is not long this year, owing to the suspension of a number of prizes presented annually for engineering achievement. The City of Philadelphia, acting under the recommendation of the Franklin Institute, awarded the John Scott Legacy Medal and Premium to Arthur Atwater Kent, for his "unisparker," an essential element of the Atwater Kent ignition system for automobiles, and to Elmer Ambrose Sperry, for his gyro-compass. C. C. Moore was president of the Panama-Pacific Exposition and Col. G. W. Goethals honorary president of the International Engineering Congress, held during the fair. Of the various engineering societies closely related to the power-plant field, the following men were elected to the presidencies:

Dr. D. S. Jacobus, American Society of Mechanical Engineers; J. J. Carty, American Institute of Electrical Engineers; E. W. Lloyd, National Electric Light Association; Walter H. Damon, National Association of Stationary Engineers; Dwight D. Kimball, American Society of Heating and Ventilating Engineers; D. S. Boyden, National District Heating Association; Theodore Vilter, American Society of Refrigerating Engineers.

Necrology

A number of men of prominence in the field passed away. Following is a list recorded in the files of *Power*: Joseph Grant McCollum, superintendent of construction of the Essex power station of the Public Service Electric Co. of New Jersey; Frank W. Jenkins, widely known as an expert in hydraulics and connected with the Henry R. Worthington Co. for over fifty years; John Quinn, efficiency engineer of the Mingo Steel Works and Furnaces; H. Ward Leonard, the well-known electrical engineer and inventor of the Ward Leonard system of motor control; Hon. Charles A. Schieren, millionaire philanthropist and president of one of the greatest belting concerns in the world; William H. Armstrong, grand worthy chief of the Universal Craftsmen Council of Engineers; F. W. Taylor, originator of the Taylor System of scientific management; A. R. (Dick) Foley, widely known among engineers, representative of the Home Rubber Co.; Samuel C. Midlam, oldest engineer in United States in point of age as well as service; William Naylor, a friend of every operating engineer in and about Chicago; Charles E. Chinnock, one of the pioneers of the electric-light and telephone industries; Austin Lord Bowman, one of the foremost bridge builders and engineers in the country; Rear Admiral Isherwood, engineer-in-chief of the United States Navy during the Civil War and one of the founders of the experimental theory of the steam engine; Ben B. Lamprey, inventor of the Lamprey arch plate and other devices for low-pressure steam boilers; William H. Cronley, engineer of the city hall, Jersey City, and member of the city's board of examiners. Allen Wood Swift, founder of the Swift Lubricator Co.; Andrew Allan, Sr., founder of the firm of A. Allan & Son, which makes the "Allan Metal" bearing alloys; Charles H. Weeks, identified with Buckeye Engine Co. for over forty years; William H. Gerrish, chief smoke inspector for the Massachusetts Gas and Electric Light Commission; Joseph A. Holmes, director of the Federal Bureau of Mines; William Kerr, who operated the first turbine in Chicago; George R. Stetson, formerly president and general manager of the New Bedford Gas and Edison Light Co.; Charles A. Potter, chief engineer of the New Bedford, Nantucket & Martha's Vineyard Steamboat Co.'s fleet; John H. Warder, secretary of the Western Society of Engineers; Cornelius J. Field, at one time general manager of the Brooklyn Edison Co. James M. Dodge, the originator of chain transmission in power installations and chairman of the board of directors of the Link Belt Co.

Correspondence

Removable Coverings on Boiler Joints

In the issue of Nov. 23, page 724, editorial comment was made on the amendment to the Massachusetts boiler rules, proposed by a member of the Boiler Inspection Department, making compulsory the removing of coverings over longitudinal seams of boilers at the time of inspection.

No better proof of the necessity for its adoption could be given than the experience of its advocate, Mr. Morton, who on Nov. 26 took this means of inspecting a boiler and found defects serious enough to warrant its being condemned. This boiler had been leaking from a lap crack for some time. Had only the ordinary inspection methods been carried out, undoubtedly Massachusetts would have had another boiler explosion, caused by the most common of serious defects.

In East Weymouth, Mass., an explosion recently occurred, the cause of which was a lap crack, and Mr. Morton contends that the sheet from this boiler showed a leakage from a lap crack. After a lap crack was found in a sheet of the boiler on the "Monitor," a steamboat conveying passengers in Boston Harbor, this test was applied and it revealed cracks in other sheets of the same boiler.

After these findings and in view of the fact that boilers are inspected to find weaknesses, it seems that the most practical proceeding would be to make removable coverings compulsory. That the rule originated with, and its adoption is advocated by, a member of the Boiler Inspection Department should give force to it.

States that already have or are considering a set of boiler laws would be acting wisely to include this proposed amendment.

WALLACE WHITLOCK.

Lynn, Mass.

Why Water Tubes Bend Upward

Although a little late, I have read with interest J. C. Hawkins' article "Boiler Tubes Have Tendency to Spring Upward," on page 452 of *Power* for Sept. 28, 1915. I do not agree with Mr. Hawkins as to the reason for the tubes in Stirling boilers springing upward instead of downward. If his reasoning were correct this condition would occur in all Stirling boilers, whereas I have seen many in which the tubes remained in the same shape they were in when installed. This condition of warping occurs only when the tubes have an internal coating of scale.

Forces tending to bend the tubes upward in a Stirling boiler are the same as those existing in straight-tube boilers such as the Babcock & Wilcox and the Heine, in which it is also found that when the tubes are coated with scale they bend upward rather than downward. It is also observed, when examining such tubes, that they show signs of burning on the fire side, usually being colored a dark red on this account. This shows that Mr. Hawkins is wrong in his contention that the tube is hotter on the side away from the fire than it is on the fire side.

The explanation of why the tubes bend upward is simple. Take first a straight tube in a Babcock & Wilcox boiler. Being coated with scale, it cannot pass the heat from the fire direct to the water and consequently becomes overheated. As all the radiant heat acts only on the fire side, the tube becomes much hotter on that side than on the side away from the fire. This difference in temperature causes the tube to expand more on the fire side than on the other, and this expansion is resisted by the boiler headers. The result is that the tube becomes practically a column with an eccentric load, the greatest load acting on the side of the tube in which the greatest expansion occurs. Like any other column with an eccentric load, the tube finally gets into a condition of having to withstand a severe compression on the fire side and tension instead of compression on the side away from the fire. These forces tend to bend the tube upward.

San Francisco, Calif. C. H. DELANY.

Cutting Down Cylinder Oil

In regard to the question of how much cylinder oil should be used, I submit the conditions and the amount of oil that our engines are using and the cost of the same. The steam pressure is 100 lb., saturated, with the main line dripped to a Holly system and a separator placed above the throttle on each engine. The piston speed is 600 ft. per min., diameter of cylinder 19 in., with four Corliss-type nonreleasing valves, speed 200 r.p.m. The oil costs about twenty cents per gallon, on yearly contract. We are using an average of five pints in twelve hours' run in each engine.

The area of the cylinder walls wiped over per day is approximately 2,160,000 sq.ft., neglecting the valves, which are of the double-ported skeleton type. This is one quart of oil for approximately each 864,000 sq.ft. wiped over. The cylinder oil costs about thirteen cents per day per engine or about 0.006c. per 100,000 sq.ft. of cylinder area wiped over. The engines run quietly, and the valves and cylinder walls seem to be sufficiently lubricated.

The piston rods are packed with metallic packing which has been in place several years, and although it leaks a little, no oil is used on the rod except what works out with the steam and the oil from the crosshead that splashes on the rod and works back through the separating plate between the guides and the cylinder.

The three main engines are operated in rotation, and each runs an average of 140 hours a month. The main bearing, crank and crosshead are lubricated from an individual gravity-feed oiling system. The oil is changed about once a month, but would run longer if necessary. The oil removed is filtered, the systems being filled with

new oil. Each engine requires 5 gal. per month at 19c. per gal. The filtered oil is used on valve gears, eccentrics and principally on auxiliary machinery. The eccentrics and valve gears are lubricated with grease cups, but some filtered oil is used at intervals. The eccentrics use approximately 5 lb. of grease per month in spring-compression cups; this costs 15c. per lb. The valve gears use 8 lb. per month of a cheaper grade of grease at 5c. per lb. Some of this, however, is wasted in screwing the cups down too much. About 5 gal. of oil is used in the outboard bearing, which is renewed once a year.

The total cost of lubrication for each engine per month is:

Cylinder oil, 7¼ gal. at 20c. per gal.	$1.45
Engine oil, 5 gal. at 19c. per gal.	.95
Grease, 5 lb. at 15c. per lb.	.75
Grease, 8 lb. at 5c. per lb.	.40
	$3.55

The energy generated by each engine per month is approximately 5,630 kw.-hr., and the cost of each engine's lubrication is approximately 0.00063 per kilowatt-hour generated. The engines operate as a rule at about ¾ load, and if they were operated at full load the cost of lubrication per kilowatt would be less.

Hyattsville, Md. J. C. Hawkins.

Quick and Cheap Repair Job

I have read with interest R. L. Ellis' account, on page 594 of the issue of Oct. 26, of quick work in retubing a Heine boiler, and also the data on rolling tubes by Mr. Gisztn, on page 762 of the Nov. 30 issue. Mr. Ellis' man must be "some tube roller" to properly roll 138 tubes in 10 hours. Mr. Gisztn, too, would have to work right along to average one tube in ten minutes. I have rolled 125 3¼-in. tubes in a Stirling boiler in 15 hours and had to work hard to do it, notwithstanding that only a few turns of the roller were necessary, as the tubes were leaking, caused by low water and had only to be rerolled. I have frequently inspected new work where water-tube boilers were being erected, but have never seen tubes put in at the rate given.

To say the least, a job done by cheap labor in record-breaking time would be regarded with suspicion by engineers, boiler makers and inspectors in any locality. I am of the opinion that very few men are capable of doing the job properly in less than 15 minutes and they cannot be engaged at $1.75 per day.

Dan L. Royer.

Milwaukee, Wis.

There has been considerable friendly criticism of a recent description by me of repairs on a Heine boiler, in which some questions are asked and some others implied. For the benefit of your readers I will try to give the information.

The whole job was done by hand except that some of the handhole plates were cleaned on an emery wheel. Most of them, however, had very little cleaning to be done, as we use lead gaskets.

Rolling the tubes was done by an ordinary laborer who had never worked in a boiler shop and hence had no preconceived notion of how many tubes constituted a day's work. Our standard time is 3½ min. per 3½-in. tube on a Heine boiler. Criticism of this time based upon the time necessary to tube a Stirling boiler would, I think, be just, as I do not believe it can be done in that type of boiler in three to four minutes, on account of the more restricted space in which the operator must work.

The whole job was laid out on a basis of scientific management and the time standardized. The working conditions were made such as to promote the comfort of the men, and they were given an incentive to do a good job and do it quickly. I think the job can be duplicated by any intelligent chief engineer who will study out the job and plan for it. I doubt seriously if it can be done by one who has never seriously contemplated a job from the standpoint of doing it in the best, easiest and quickest way.

I believe Mr. Gisztn hits the crux of the situation when he asks of men who do boiler tubing if they ever expand one end of 138 tubes in one day—he does not ask if they *can* do this without undue fatigue. I am afraid that the usual attitude is not how much may be done without undue exertion, but how little one can get by with.

R. L. Ellis.

Selma, Ala.

Peculiar Cause of Knocking

A 100-kw. direct-connected exciter set soon after erection developed a slight knock which the operators were unable to stop. It ran about four years with the sound gradually getting worse, and the operators were sure that the trouble was in the armature, which was keyed solidly on the shaft, but which gradually seemed to be getting out of balance. Finally the risers from the commutator to the armature coils began to break.

The commutator was then removed from the shaft, and the trouble was located. The armature was fitted with the usual cast-iron spider with all the laminations keyed to it with one key. The laminations were too large for the spider and had been improperly keyed on, allowing them to work back and forth on the key, thus causing the knock and finally crystallizing the risers. A new key was fitted, and the set is running quietly.

Cedar Rapids, Ia. F. W. Laas.

Soot and Its Formation

In the Dec. 14 issue W. F. Schaphorst asks if soot formation may be prevented.

There are two causes that lead to the formation of soot and smoke. Incomplete combustion, however, covers both of these causes. But incomplete combustion may be due to the lack of sufficient oxygen or to the chilling of the gases to a temperature below the combining, or igniting temperature. The latter may occur when sufficient oxygen is present for complete combustion.

In the manufacture of lampblack, which is soot, the flame from a gas jet is impinged against a sheet of cold metal. This is exactly the condition that exists in a boiler setting when the combining gases reach the comparatively cold surface of the boiler. The flame temperature will range from 2,900 to 4,000 deg. F., while the surface of the boiler will be over 1,000 deg. cooler. The natural result of this sudden chill is the cessation of combustion and the partial condensation of the hydrocarbons, with the deposition of carbon or soot on the cool surface. The only real remedy for the soot-and-smoke trouble is a combustion chamber of sufficient size to per-

mit the gases to burn completely, so that the only gases that will come in contact with the cold surface of the boiler will be the products of combustion.

Until recently few boiler furnaces have been designed with due regard to the laws of combustion.

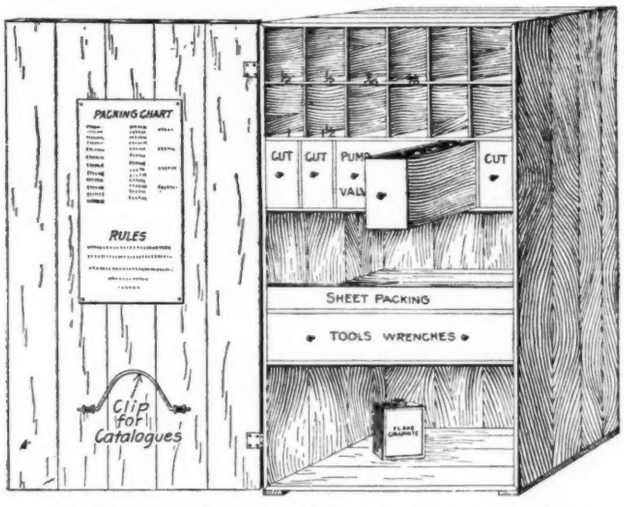
Cleveland, Ohio. A. D. WILLIAMS.

A Handy Packing Cabinet

An item of prime importance in maintenance, and one to which engineers do not often give proper attention, is packing. In this plant packing ranks third in the yearly expense bill, of course omitting labor. It is an unfortunate fact that a large percentage of the packing purchased is never used, hence the following suggestions:

Do not buy a larger quantity of any rubber goods than you are going to use in a reasonable time. Rubber is one of the things that age does not improve; in fact, it will be found to be very much the other way about. If the large jobbing houses cannot risk carrying an overstock, it is a sure thing that it is not safe for you to try it.

Have a proper place to keep your rubber supplies. It is not an uncommon thing to find packing kept in some old closet in which the junk odds and ends are



CONTAINER FOR PACKING AND PACKING TOOLS

thrown, and then to hear the engineer cuss because the packing will not stand up under high pressure.

The cupboard shown in the illustration is practical, easily made and cheap.

In the upper part are the pigeonholes, in which are kept the coils of packing that are uncut. The size is marked, and if it is to be used for any particular machine a note is made on the inside of the box.

Below are a number of drawers in which are kept the cut packings. Each drawer is divided into a number of compartments, and the size of the packing in each is marked where it can be plainly seen. The center compartment is used to hold a number of other rubber accessories, such as pump valves, valve disks and small plumbing supplies.

A compartment is provided, in which the sheet packing is kept. Nothing else should be allowed in this compartment, otherwise the packing cannot be expected to give the best service, even when it is of the best kind and quality.

Next is the tool drawer. Here all tools are kept when not in use. This makes it unnecessary to hunt the plant over for the special wrenches, the packing hooks, etc., which are needed but sometimes hard to find

Under this drawer is a space in which boxes of supplies can be kept. This is a good place to keep the odds and ends of packings, cans of graphite, etc.

On the inside of the door is a framed chart giving all the sizes of packings used in the plant, where used, and also particulars governing this work.

PACKING CHART

V—Valve stem. P—Piston rod.

Machine	Packing Size	Rod	Remarks
Engine No. 1	3/8	V	
	1 1/4	P	
Engine No. 2	1/4	V	
	7/8	P	
Engine No. 3	1/8	V	
	1/2	P	
Boiler feed pumps	1/4	V	
	5/8	P	
Hydraulic pumps	3/8	V	
	3/4	P	
Air compressor	1/4	V	
	7/8	P	
		Air	
Vacuum pump	1/4	V	
	1/2	P	
Ammonia compressor	1/4	V	
	7/8	P	
		Ammonia	Use rings marked "For ice machine"
Brine pump	3/8	V	
	3/4	P	
Circulating pump	1/4	V	
	5/8	P	

Under this chart on the door is a wire clip in which are kept the packing catalogs and any data that have value in regard to the packings used. One man on each watch has a key to this cupboard and is held responsible for its contents.

Finally, keep packing in a cool, dry place and keep oil away from it. A. D. PALMER.

Dorchester, Mass.

Accident Prevention Means

The numerous accidents and near-accidents mentioned in *Power* recently indicate the need for the engine builder and the operating engineer to get together for the purpose of preventing them by the adoption by the builder of designs that will preclude the possibility of such accidents and by careful, systematic inspection on the part of the operator. Manufacturers cannot be blamed for setscrews, follower nuts, etc., working loose but they can frequently employ designs that would obviate such occurrences.

The builders were not in the least to blame for the near-accident described by me on page 592, Oct. 26, especially in view of the fact that another engine of the same size and type had given no trouble, although it had not been inspected since installed nine years previously. Both the piston rods were decidedly out of center, and the metallic packing was ruined, which was sufficient evidence that the pistons needed centering in the cylinders.

Unquestionably the solid type of piston with snap rings is safer than the built-up type with centering screws and follower plate. The latter type is, however, much more convenient and better adapted to the larger sizes. It is surprising that more accidents do not occur from loose and broken follower nuts and studs. Follower studs fail from two causes—being too small or of defective material. They should never be smaller than 7/8 in. dia. Follower nuts should draw up snug all the way, in rota-

tion, then the stud should be lightly peened. If this is done the nuts will never work loose.

A plan that I have found most successful while centering is to tighten the setscrews evenly and snugly, then after drawing up the locknut (holding centering screw with another wrench very tightly) use a hammer in driving the locknuts home. This last operation backs off the setscrew slightly, which prevents any binding of the junk ring. Centering screws adjusted and locked in this way will never work loose.

A mysterious pound in a tandem engine was caused by the follower studs being forced through the piston proper, one of them more than ¼ in., so that they struck the front cylinder head. The nuts had stuck and forced the studs through too far. Of course this was both faulty workmanship and design, since the studs should have been pulled up to the end of the thread or to shoulders at the outset, and the holes should not have been drilled entirely through.

In another tandem compound engine the pistons would tap the head end of the high-pressure cylinder or the crank end of the low-pressure. The engineer said this condition had existed for more than 1½ yr. since the cylinders had been rebored and new pistons put in, although the piston was purchased from the engine builders and the work was done by them. Several cuts had to be taken off the low-pressure crank-end head before the noise disappeared.

In another case a cross-compound engine was considered a "hoodoo." It shook, pounded, rattled and knocked. As there was no engineer, the master mechanic did all of the keying and adjusting, while a boy just out of college took indicator diagrams weekly and figured the horsepower. All the engine needed was keying up and slight adjustments to valves and governor, to make it run quietly. In conclusion I would say:

1. The engine builders should adopt such designs as would make impossible many of the failures that have occurred in the past.

2. The owners should secure the services of experienced high-class engineers skilled in the maintenance and operation of the particular apparatus in hand.

3. Engineers worthy of the title should carefully inspect all details of the various apparatus in their charge.

It might be well for the stationary fraternity to imitate the methods in use by some of the large railway systems; that is, to engage a specialist for the purpose of making inspections and reporting weak parts or improper conditions, so that accidents might be averted.

Unquestionably it would be well to pay a bonus to employees that report weaknesses or improper conditions in the plant. WALDO WEAVER.

Beacon Falls, Conn.

Results of Eight Boiler Tests

The days are growing shorter, and some of us that don't have much to do (?) will soon be seeking ways and means to pass away the long evenings. To break the monotony, I would suggest that we might start something in the way of good-natured discussion on the relative performance of our respective plants, so here goes!

I do not wish to appear egotistical, but I claim that we (the Boston Woven Hose and Rubber Co.) have the most economical plant in combined boiler and furnace efficiency. This claim is based on eight tests, run at different times and intervals and at different ratings, that were made alternately by the Stone & Webster Engineering Corporation and the regular station crew, each checking the other. The results of all tests, finally checked by D. S. Jacobus (an expert on boiler tests), are given in a condensed form in the accompanying table. Now, boys, sharpen your pencils, and go to it. I claim the championship until some other fellow can show better results.

SUMMARY OF RESULTS OF TESTS MADE ON NO. 1 BOILER

Test	Combined Boiler and Furnace Efficiency	Per Cent. of Boiler Rating	Water f. and a. 212 per Lb. Dry Coal	Lb. Coal per 1,000 Lb. Water	B.t.u. per Lb. Dry Coal	Ash per Lb. Dry Coal	Cost of Coal per 1,000 Lb. Steam
1	78.90	138.3	11.93	96.86	14,670	6.12	$0.188
2	80.61	143.5	12.17	84.71	14,659	6.57	.1645
3	80.18	169.0	12.22	84.56	14,785	6.11	.1641
4	82.74	139.1	12.39	83.60	14,534	7.09	.1624
5	78.87	93.4	11.85	86.60	14,588	6.44	.1682
6	78.00	173.4	11.45	90.15	14,246	8.57	.1750
7	76.47	204.4	11.36	89.92	14,428	7.79	.1746
8	82.60	135.3	12.27	84.10	14,421	7.99	.1633

Price of coal, $4.35 per ton (2,240 lb.), or $0.001942 per lb.

Boston, Mass. J. C. LONG.

Loud-Sounding Telephone Call

In most power plants it is difficult to hear the telephone bell, even if a large one is used, on account of the noise, and quite often great annoyance is caused thereby.

In one plant this has been happily overcome by attaching to the telephone booth and wiring to the telephone one of the electric horns so commonly used on automobiles. Current to operate the horn was at first taken from batteries, but later the horn was wired to the exciter panel of the switchboard and the current was regulated by a small bank of lamps, which of course only light when the horn is in use. The batteries are now used only when the plant is all shut down. The device is a great success, as it can be heard anywhere in the plant and even in the yard outside. By operating by hand the drop that sounds the horn, any desired person can be called by prearranged signals for the various employees, who may be wanted at the phone or on the engine-room floor.

For instance, two might be for the chief engineer, three for the operating engineer, etc. The horn may also be used for a variety of purposes—for example, in case of fire, so that the proper person would at once start the fire pump, while the others would go to their proper stations.

Somerville, Mass. J. M. COLEMAN.

Vertical Belt Gave Trouble

In the plant where I am employed there is an 18-in. vertical belt which formerly gave a lot of trouble by slipping, although there is an idler attached that can be used when the load is thrown on in the evening. It is used to drive the dynamos that light the mills, but the voltage dropped from 110 to 100 sometimes.

One night last winter it was slipping badly and I was about to apply the "last resort" (rosin), when one of the shop hands suggested that I try lime made into a thick paste. To my surprise, as soon as a little of this was applied the voltage went right up to where it belonged, and it stayed there even after the idler was slacked up. A vertical belt is a constant care and should never be used if it can possibly be avoided.

Although I have been using lime on that belt for a year, it is not injured in the least. F. P. KINDER.

Saxonville, Mass.

Inquiries of General Interest

Thickness of Boiler Shells for Different Diameters—How does the thickness of a boiler shell vary with relation to the diameter? L. G.

For the same safe working pressure, same tensile strength of material and same percentage of efficiency of joint, the required thickness of the shell will be directly in proportion to the diameter.

Ignition Temperature of Carbon—What is the ignition temperature of carbon? J. R. B.

The state determines the temperature, which is lower for porous varieties of charcoal, higher for denser varieties and still higher for graphitic forms—all forms that react with oxygen yielding carbon dioxide at some temperature. These phenomena would seem to suggest that there is no exact ignition temperature of carbon.

"Lost Motion" of Duplex-Pump Valve Gear—Can an ordinary duplex pump be run without lost motion of the steam valves? E. G. K.

Lost motion of the steam valves is essential for the steam ports to remain uncovered for the passage of steam during the continuance of the strokes. The term "lost motion" is not to be regarded as equivalent to an undesirable "backlash" due to crude construction, but as an intentional means of securing pauses of the valves that are necessary for operation of the pump.

Coal and Combustible per Kilowatt-Hour—For a 24-hr. run of a direct-current plant the log readings were as follows: Average amperage, 4,820; voltage, 110; total coal fired, 50,700 lb.; total ash, 12,550 lb. What was the number of pounds of coal and pounds of combustible per kilowatt-hour? B. T.

The total output was $\frac{(4{,}820 \times 110)}{1{,}000} \times 24 = 12{,}724.8$ kw.-hr.; hence the coal used was $\frac{50{,}700}{12{,}724.8} = 3.984$ lb. per kw.-hr., and the combustible was $\frac{50{,}700 - 12{,}550}{12{,}724.8} = 2.998$ lb. per kw.-hr.

Power Required for Lighting vs. Motor Load—Is any more power required to generate electric current for a 20-amp. lighting load than for a 20-amp. motor load? H. C. B.

For direct current the power required would be the same. With an alternating current the power factor enters the question, as, for example, if the power factor is 85 per cent. with a motor load of 20 amp. flowing, the circuit would represent less output and less load on the engine than 20 amp. flowing in the circuit with a lighting load, because with a motor load the amperage would be wattless.

Thermal Efficiency of Engine—If the steam consumption of a noncondensing engine per brake horsepower per hour is equivalent to the evaporation of 34½ lb. of water from and at 212 deg. F., what percentage of the heat of the steam would be realized? E. T. B.

A brake horsepower is the development of work at the rate of 33,000 ft.-lb. per min., and for all practical purposes 1 B.t.u. may be taken as equal to 778 ft.-lb. and 1 brake horsepower per hour as equivalent to $\frac{33{,}000 \times 60}{778} = 2{,}544.9$ B.t.u. The heat required for the evaporation of 34½ lb. of water from and at 212 deg. F. is $34\frac{1}{2} \times 970.4 = 33{,}478.8$ B.t.u., and therefore the percentage of heat realized by the engine would be $\frac{2{,}544.9 \times 100}{33{,}478.8} = 7.6$ per cent.

Knock in Engine with Reduced Steam Pressure—Since lowering the pressure of steam supplied to an automatic high-speed engine there is a knock in the engine when carrying the full load or whenever the steam pressure drops about ten pounds. What may be the cause and remedy? E. W.

For the same full load as formerly but with lower initial pressure of the steam, cutoff takes place later in the stroke and the forms to which the connecting-rod brasses, crankpin and crosshead pin may have previously become worn are not adapted to the new distribution of pressure without making a knock in the engine. If the governor is of a type in which variation of cutoff is effected by moving the eccentric across the shaft, later cutoff would be accomplished by greater travel of the valve than formerly, and a knock may result from the valve riding over shoulders previously worn in the valve seat. If the wear of the connecting-rod brasses and pins is slight, trouble from that cause usually can be removed by keying up the brasses. A knock resulting from the formation of shoulders on the valve seat can be removed by refacing the valve seat. Knock also may be due to the valve becoming unseated from compression of the exhaust to a pressure higher than that in the steam chest, causing the valve to slam on its seat.

Output of Direct-Connected Generator—A 10x10-in. engine having a piston rod of 1.5 in. in diameter and running 220 r.p.m. developed 70 lb. m.e.p. in the head end of the cylinder and 67 lb. m.e.p. in the crank end. The mechanical efficiency of the engine is 82 per cent., and it is connected to a direct-current generator of 95 per cent. efficiency. If the voltage is 110, what will be the output of the generator under the conditions stated? E. T. B.

The area of the cylinder-head side of the engine piston is $10 \times 10 \times 0.7854 = 78.54$ sq.in., and as the cross-sectional area of the piston rod is $1.5 \times 1.5 \times 0.7854 = 1.767$, the net area of the crank side of the piston would be $78.54 - 1.767 = 76.773$ sq.in. and therefore the power developed would be

$$\frac{[(78.54 \times 70) + (76.773 \times 67)] \times \frac{10}{12} \times 220}{33{,}000} = 59.11 \text{ I.hp.}$$

If the mechanical efficiency of the engine is 82 per cent. and the efficiency of the generator is 95 per cent., then the output of the generator is $59.11 \times 0.82 \times 0.95 = 46.05$ hp., or $46.05 \times 0.746 = 34.35$ kw., and if the voltage is 110 then the output of the generator would be

$$\frac{34.35 \times 1{,}000}{110} = 312 \text{ amp.}$$

An engine efficiency of 82 per cent. is low and a generator efficiency of 95 per cent. is unusually high for a generator of the given type and size.

Power Developed by Current Waterwheel—What power would be developed by a waterwheel 20 ft. diameter by 20 ft. long with flat radial floats, if mounted on pontoons anchored in a stream at a place where the velocity of the water is 4 ft. per second? D. A. S.

When waterwheels of the type stated have radial floats or paddles, they are most efficient when the radial breadth of the floats is about one-fourth the greatest radius of the wheel. With the floats spaced that distance apart and the speed of the middle of the floats about one-half the velocity of the water and with only so much of the wheel lowered into the water as to insure complete submergence of each float, then the efficiency is about 40 per cent. of the kinetic energy of the cross-section of water intercepted. Having a wheel 20 ft. in diameter by 20 ft. long, floats 2.5x20 ft. would intercept 50 sq.ft. of the cross-sectional area of the stream.

The kinetic energy of the water would be given by the formula

$$K = \tfrac{1}{2}MV^2,$$

in which

K = Energy in ft.-lb. per sec.;
M = Mass of water presented per second;
V^2 = Square of the velocity in ft. per second.

Then as the velocity of the stream is 4 ft. per second and

$$M = \frac{W}{g}, \text{ or } \frac{(50 \times 4) \text{ cu.ft.} \times 62.3 \text{ lb. per cu.ft.}}{32.2}$$

by substitution the formula gives, for energy of the water,

$$K = \tfrac{1}{2} \text{ of } \frac{(50 \times 4) \times 62.3 \times 4^2}{32.2} = 3{,}095.65 \text{ ft.-lb. per sec.}$$

and with 40 per cent. efficiency the wheel would develop 40 per cent. of 3,095.65 = 1,238.24 ft.-lb. per second or

$$\frac{1{,}238.26}{550} = 2.25 \text{ hp.}$$

Hydraulic Power Plant at Henry Ford Farms*

By Mark A. Replogle

SYNOPSIS—The hydraulic power plant at the Henry Ford Farms, Dearborn, Mich., contains two turbines designed to develop 85 hp. each at 110 r.p.m. under 8-ft. head, together with electric generators. The plant supplies current for light, heat and power for Mr. Ford's residence, for the village pumping station and for the miscellaneous requirements of the farms. It was built to operate under somewhat unusual conditions of head and contains novel features.

The plant of the Henry Ford Farms is on the River Rouge, near its junction with the Detroit River, which latter varies considerably with the levels of the Great Lakes. The Rouge River is subject to the widest extremes in flow. At the point of location of the plant is a dam over which the normal run-off is 100 sec.-ft. There are short intervals of a few hours, however, when the run-off fills the valley with water so that no sign of the dam is apparent; at these times the head over the dam is completely destroyed. There are longer periods when the level is affected by the Great Lake conditions, causing back water in the tailrace and consequent lowering of the head for days at a time. Also, there may be weeks of surplus flow at semi-high head. The conditions may be summarized as low water with normal head; low water with head lowered by Great Lake conditions; normal flow under variable heads; high water with approximately half normal head, which is also variable and dependent upon Great Lake conditions; and very high water, but with head almost destroyed.

High water, with head varying from 2 to 5 ft., may persist for weeks at a time, so that provision to meet this condition was necessary. The condition of very high water but practically no head only obtains for a few hours at a time, and no adequate provision can be made for it except the steam reserve.

The power house is a concrete structure. The foundation consists of a monolith of reinforced concrete. Conditions made it necessary to floor the headrace, power-house site and tailrace with concrete for several feet in thickness. The headrace, 31 ft. wide and 10 ft. deep, was arched over for approximately 150 ft., and the tailrace was similarly arched, both for architectural reasons.

The three-story power house is shown in cross-section in Fig. 1. The lower floor contains the two turbines, the middle contains the auxiliary apparatus for controlling the turbines, and the upper the two dynamos, the governors, the switchboard and one steam reserve unit. The turbine floor is divided into three separate penstocks connected by an overhead gallery.

Ordinary precaution led to the provision of two units, each having the capacity of the normal flow of the stream under 8-ft. head. The speed of 110 r.p.m. was established for full-head conditions and this speed was maintained at all heads, varying from 1 ft. up to the full head of 8 ft. Herein lies the unique feature of this plant—the maintenance of full speeds and good power through a wide range of low heads and in the face of the condition that, under ordinary settings, the turbines employed require slightly over 4 ft. head to bring them to maximum speed at full gate and no load conditions.

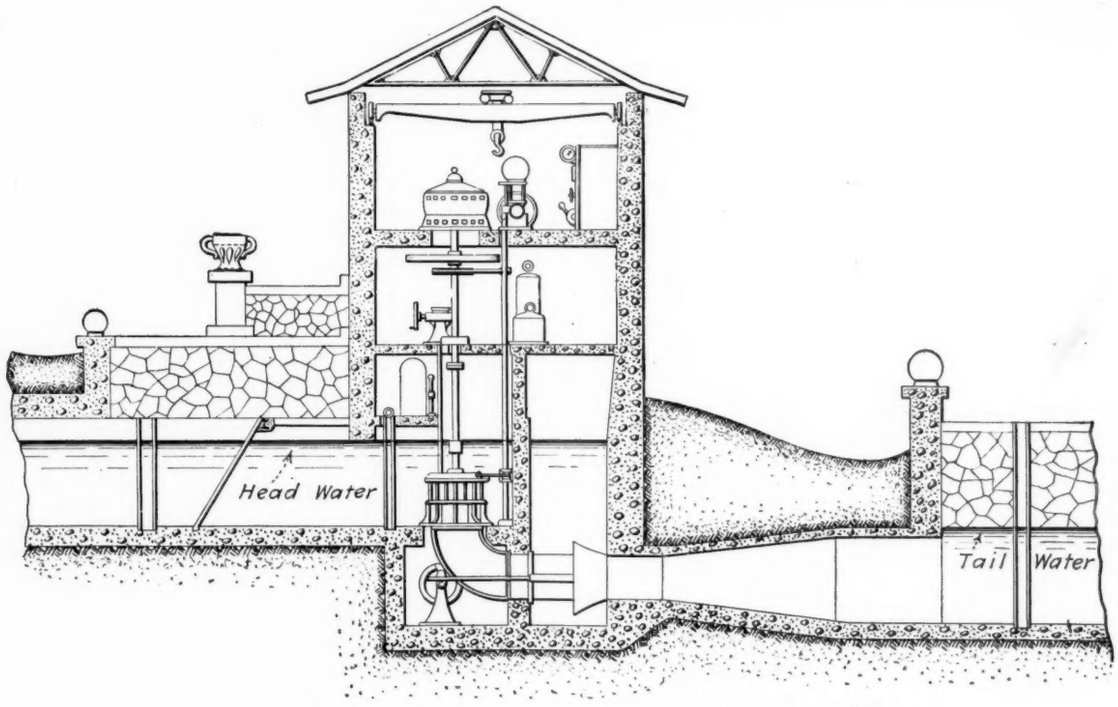


FIG. 1 CROSS-SECTION OF POWER HOUSE AT THE HENRY FORD FARMS

The vertical-type turbines are of 85-hp. capacity, when operating under 8 ft. head at 110 r.p.m. They have wicket gates, operated by draw-rods from a gateshaft reaching to the governor arm. The turbine chambers are scroll-shaped, arranged for their respective right- and left-hand turbines. The weight of the runners is sustained by roller bearings on top of the generators. All of the under-water shaft bearings are of bronze.

The two direct-current turbo-generators are of the vertical type, 55 kw. each, at 250 volts, and have ample overload capacity. Each is self-contained, having on top a roller bearing which supports all the rotating parts, including the balance wheels and turbines. A third steam-engine generator is provided. This is horizontal and is of 35-kw. capacity at 250 volts. The governors are vertically driven, and direct-connected. They are of the open system, oil-pressure type. Full

*From a paper read at the annual meeting, December, 1915, of the American Society of Mechanical Engineers.

apparatus is provided in the top floor of the power house for recording test conditions.

The three penstocks on the lowest floor can be closed by folding headgates, manipulated by the overhead crane. Of these penstocks, the middle one is a common feeder for the others, each of which contains what has been termed a "turbine-discharge accelerator." These accelerators are a

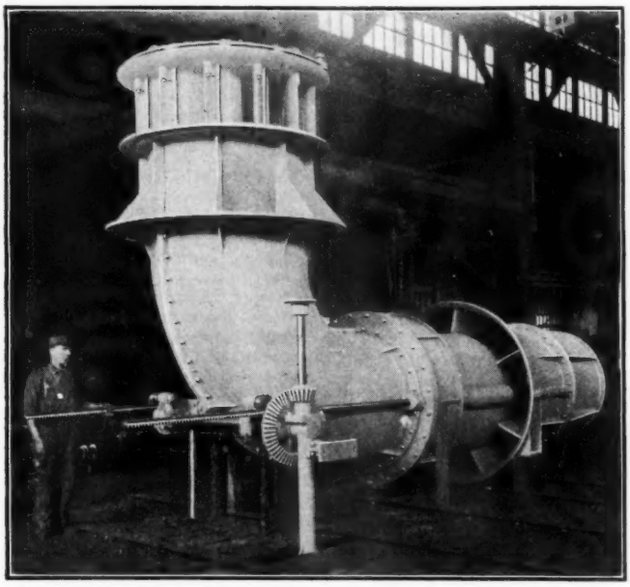


FIG. 2. 85-HP. TURBINE WITH DISCHARGE ACCELERATOR

form of draft tube, into which each turbine discharges and into which, also, water from the headrace is discharged through a feeder. The headrace water accentuates the turbine flow through the draft tube, having the same effect as an added head of headwater. An illustration of one of the turbines with accelerator is shown in Fig. 2.

The purpose of the discharge accelerators is to transfer energy from surplus water (otherwise running over the dam

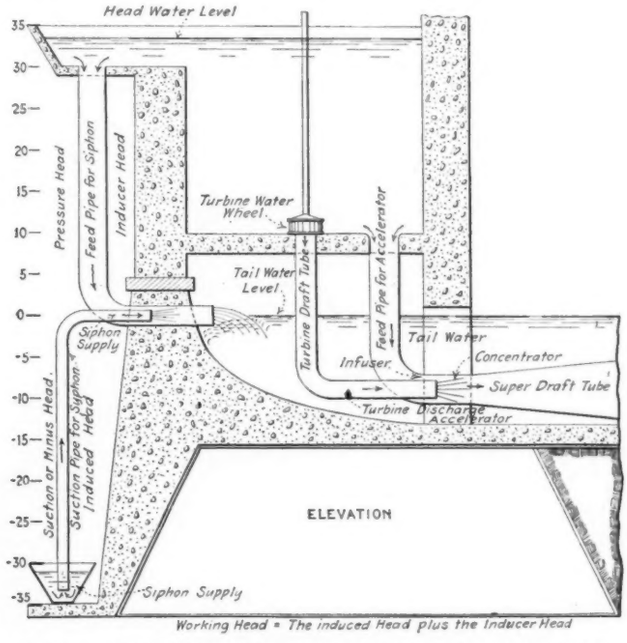


FIG. 3. COMPARISON OF SIPHON AND ACCELERATOR

or wasting) to the turbines, augmenting their power under subnormal heads after they have reached their otherwise full power at those heads. Their effect is to boost the power of the turbines, working under low-head conditions, beyond that which the conditions would seem to warrant.

The principle of the accelerator may be followed by reference to Fig. 3. In this figure is also shown a common siphon for purposes of comparison. In the case of the siphon, the induced, or suction, head cannot be greater than the inducer, or pressure, head. With the accelerator, the induced head may be greater than the inducer head. The accelerator is not an ejector.

The effect of the accelerator on the turbine is to partly remove the pressure at the discharge end without changing that at the intake end. Under ordinary conditions the pres-

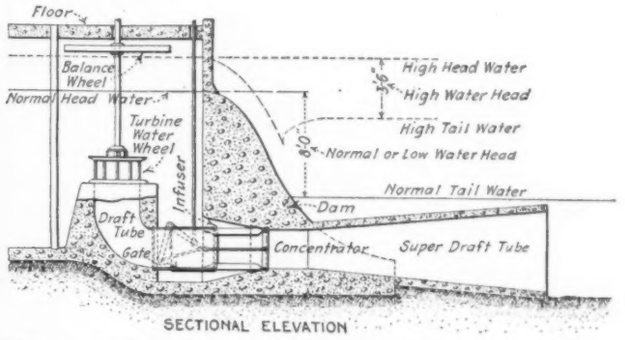


FIG. 4. 85-HP. TURBINE AND DISCHARGE ACCELERATOR

sure on both the head and tail water is 14.7 lb. per sq.in. alike. If the turbine were to discharge into tail water the pressure on which was, say, only 10 lb. per sq.in., the result would be the equivalent of adding slightly over 10 ft. head to the turbine, and as far as practical results were concerned the turbine would now develop energy corresponding to the increased head.

Each accelerator consists of a super draft tube, a concentrator and an infuser, Fig. 4. The infuser is provided with a gate, by means of which the amount of accelerator water may be varied at will or shut off entirely, in the latter case leaving only the turbine discharging into the super draft tube.

The area of cross-section of the concentrator is less than that of the turbine-draft tube. The effect of this narrowed

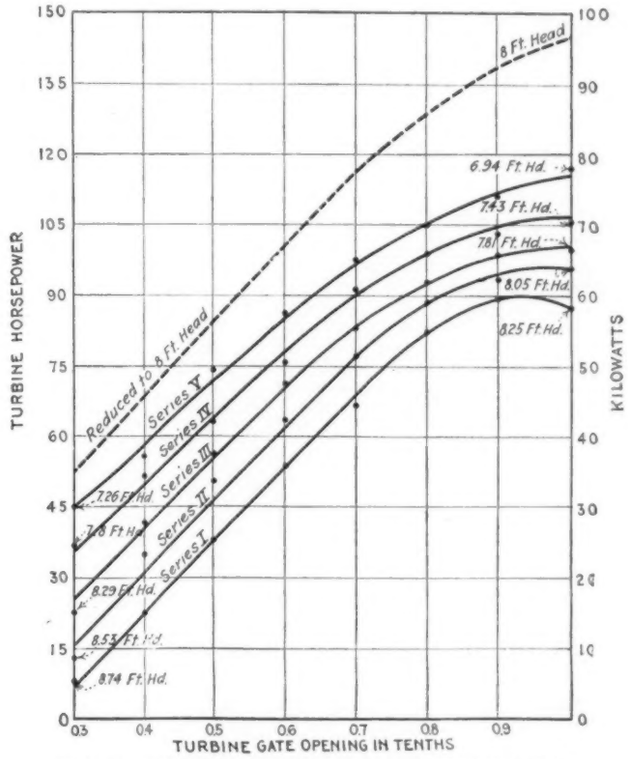


FIG. 5. RESULTS OF TESTS ON ACCELERATOR

section on the turbine's discharge during its ordinary operation was in doubt during the construction period, but when the installation was completed tests showed that the effect was negligible.

A series of tests was made on the accelerator of one unit on Mar. 18, 1915, and the results are plotted in Fig. 5. In this figure, the scale of turbine horsepower is given on the left, kilowatts on the right and turbine gate opening in

tenths below. A normal speed of 110 r.p.m. was maintained throughout the tests. The energy was absorbed by a water rheostat, and the power was measured by the switchboard instruments, which are new, therefore substantially correct.

The purpose of Series I was to show the maximum power of the turbine when the accelerator gates were closed. The curve shows approximately 90 turbine hp. at between $\frac{9}{10}$ and full gate, but the head was slightly over 8 ft.

Series II shows readings made at the same turbine-gate openings, but the accelerator gate was open 20 per cent. of its range throughout the series. Although the actual head is lowered, there is an actual increase in power.

Series III was made with the accelerator gate open about 40 per cent. of its travel. This resulted in a still further increase of power.

Series IV was made with the accelerator gate open about 60 per cent. of its travel. Throughout this series, the accelerator was sucking some air, but the power increased.

Series V was made with the accelerator gate open about 80 per cent. of its travel. The accelerator sucked air violently during these last readings, but the power increased even though the head was less than 7 ft. The excessive taking in of air prevented the further opening of the accelerator. Therefore its limit of action is unknown.

The curve in Series V shows 116 turbine hp. at 6.94 ft. head. This curve, reduced by the well-known formula to an 8-ft. head, shows that 143.5 hp. can be obtained by the use of the accelerator from an 8-ft. head in connection with the identical turbine that had been guaranteed to develop 85 hp. under 8-ft. head.

There seems to be every reason to believe that full turbine power from a water turbine can be obtained from all the water used (when based on the actual or working head) even though only a portion of the water passes through the turbine proper. A water power equipped with an accelerator can be speeded for full head at low-water condition, and the same turbine can have its capacity practically doubled under the same head, if sufficient water is available. The power unit can develop its normal rated power at one-half head when sufficient water is available, and the turbine can furnish considerable power when the working head is less than 25 per cent. of the normal head, and all this may be done at good efficiency.

A like reflection will show that with this system many water powers may become independent of steam or gas reserves, with the saving of the large expense these auxiliary power units now entail With the accelerator, too, it is not necessary to provide so many power units in a given development, as the elasticity permits of good efficiency with fewer turbines.

There are many cases in which low heads only are available and the water cannot be utilized practically and profitably. The accelerator can be used to boost the head in such cases to an amount at which development of the water power is possible. The accelerator can convert an actual head of 3 to 10 ft. into a working or effective head of 8 to 20 ft.

Processes of Electric Welding*

By C. B. Auel†

SYNOPSIS—Describes various processes of electric welding. Boiler-tube welding a good field for the application of the Slavianoff process, as shown by the Pennsylvania R.R. Comparison of costs of smiths' welding and electric welding on similar pieces.

[The growing application of welding to the repair of power-plant equipment makes it important that the engineer become familiar with the different processes.—Editor.]

Electric welding can be accomplished by any one of several processes, but none is of universal applicability; that is to say, each one is more or less limited to a certain field as well as to a given range in such field. Furthermore, there is little advantageous overlapping of their respective fields, so that the processes are supplementary to one another rather than complementary.

There are three clearly defined processes—arc, incandescent and electro-percussive—of which the last mentioned is recent. The first two are capable of subdivision—the arc into the Zerener, Benardos and Slavianoff processes; the incandescent into the La Grange-Hoho and Thomson processes. The differences between them may be stated as follows:

Arc (Direct Current)

Zerener: Arc drawn between two carbon rods which form the electrodes and directed on metal to be welded.

Benardos: Arc drawn between carbon rod, which forms one electrode, and metal to be welded, which forms the other electrode.

Slavianoff: Arc drawn between metal rod, which forms one electrode, and metal to be welded, which forms the other electrode.

Incandescent (Direct Current)

La Grange-Hoho: Metals to be welded form one electrode of acidulated bath; large conducting plate forms the other electrode. Metals butted together after reaching incandescence.

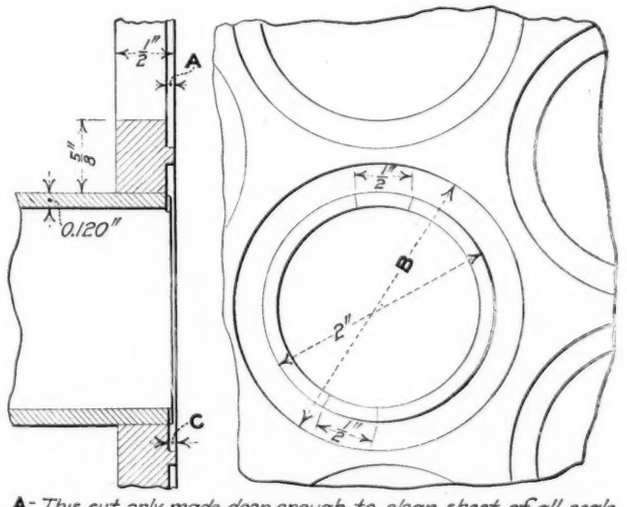
Thomson (alternating current): Metals to be welded form the electrodes; butted together under pressure, causing high resistance contact with heating.

Electro-Percussive (Direct Current)

Metals to be welded form the electrodes; brought suddenly into percussive contact and vaporized.

The arc processes are autogenous in that welding can be accomplished without pressure, simply by allowing the metals to melt under the influence of the electric current, then to mix and unite as they cool; the incandescent and electro-percussive processes, however, invariably require pressure as a necessary adjunct to their successful accomplishment.

The carbons should be solid, not cored; should neither crack, crumble nor spindle, and should preferably be



A- This cut only made deep enough to clean sheet of all scale and make right angle at edge of flue hole.
B- From $2\frac{1}{2}$ to $2\frac{3}{4}$ in. depending on condition of sheet.
C- From 0 to $\frac{1}{16}$ in.

HOW TUBE PLATE IS PREPARED FOR WELDING TUBES

"graphitic" rather than "common," as the former type is of higher electrical as well as thermal conductivity.

Metal electrodes will range from $\frac{1}{8}$ in. (0.3175 cm.) to $\frac{5}{16}$ in. (0.7938 cm.) in diameter, by approximately 12 in (30.48 cm.) in length, likewise depending upon the class of welding. For welding in wrought iron and steel, nothing can excel the genuine Norway or Swedish iron.

Electric welding, more especially when effected by the Benardos or carbon-arc process, requires, on account of the brightness of the arc, to be done in an inclosure. The operator must also be thoroughly well covered over the body, head, eyes and hands. Exposure to the arc rays, even if of brief duration, causes an irritation or inflammation closely

*Abstract of a paper presented at the International Engineering Congress, San Francisco, Calif., Sept. 20-25, 1915.

†Director: Standards, Processes and Materials, Westinghouse Electric and Manufacturing Co., Pittsburgh, Pa.

resembling sunburn, but fortunately with no more serious consequences.

Hoods may be made of canvas, sheet metal or insulating material and should be thoroughly well ventilated. The clothing is sufficient protection for the body and gloves for the hands.

As the eyes are so much more sensitive, even greater care should be taken in their protection.

FLUXES THAT ARE USED IN WELDING

A diversity of opinion seems to exist as to the value of fluxes, and many operators have their own secret formulas. It may be stated, however, that no flux is needed for welding either wrought iron or steel, the field to which arc welding has thus far proved to be particularly adapted.

For welding wrought iron or steel, various filling materials may be used, among them being Norway- or Swedish-iron rods, boiler iron, scrap, bits of steel castings, etc.; for cast or malleable iron, Norway- or Swedish-iron rods or special cast-iron rods with a high percentage of silicon.

In joining two pieces of any but the thinnest sheet metal, the abutting edges should first be chamfered at an angle of about forty-five degrees, either from one or both sides, depending upon the thickness of the material, and the chamfer should extend entirely through the thickness of the plates.

As soon as the weld has been completed and while still at a white heat, it should be briskly hammered to give the metal a finer grain. All oxide and other impurities should, of course, be kept out of the weld.

Heating the metal preparatory to welding is always beneficial in preventing and relieving strains, but is not resorted to except in special cases. A temporary furnace, especially for large work, is easily made of firebrick when needed. Annealing is also desirable at times, but, like preheating, is not done except when necessary.

THE WELDING OF BOILER TUBES

The welding of flues in locomotive boilers offers a most fertile field for the Slavianoff, or metal-electrode, process. Several different methods of preparing the flues and the flue-sheet preparatory to welding are in use, one of the most promising being that developed by O. C. Wright, assistant engineer of motive power of the Pennsylvania Lines West. Referring to Fig. 1, the flue sheet is first countersunk around each flue hole for a width of ¼ in. (0.635 cm.) to ⅜ in. (0.9525 cm.) and to a depth necessary to give a surface of clean metal and a feather edge at the flue hole. The flues are next driven into position in much the usual manner, except that no copper ferrules are required nor is it necessary to swell the flues just back of the flue-sheet; further, the flues should project above the countersunk surface of the flue-sheet not to exceed $\frac{1}{16}$ in. (0.1588 cm.) at any point, and the flue rim should be cut away, both top and bottom, through an arc of about ½ in. (1.27 cm.), as shown. In making a weld, current of approximately 90 amperes at 18 volts across the arc is employed, the welding commencing at the bottom and working around to the top for each half. Care should be taken to play the arc on the flue-sheet immediately adjacent to the flue, rather than on the flue directly, and it is also preferable so to proportion the length of the welding rod, which should be of $\frac{5}{32}$-in. (0.397 cm.) diameter Norway iron, that each half of the weld will be made with a single electrode and if possible with one application of the arc. No flux is necessary. Including the cutting away of the rim, about twelve flues can be welded per hour.

Flues welded in this manner have been tested to destruction, withstanding a crushing force of over 30 tons (27,200 kg.) along the axis of the flue, at which pressure the flue itself failed; this as against 17 tons (15,400 kg.), at which pressure flues applied in the usual manner are found to fail.

Both of the electric-arc processes are particularly well adapted to the welding of wrought iron and steel of various kinds, and while certain other metals, including cast iron, can also be welded, the work is not, generally speaking, done to advantage over some of the other processes. Welds in cast iron will prove quite variable when made by the average operator, being frequently glass-hard (though this may not matter where no machining is done) and uncertain as to strength, so that at present it would be unwise to make any pronounced claims for arc-welding in this connection. With malleable iron the results obtained are even more variable than with cast iron. In the welding of the latter, good results are obtained by using the carbon-electrode process with a suitable cast-iron filling rod, first preheating the metal to white heat, making the weld while in this condition and then cooling gradually.

Blacksmith versus Carbon-Arc-Welded Rings: The following figures have been obtained in the works of the Westinghouse Electric and Manufacturing Co., East Pittsburgh, Penn.:

Sections	Smith Welds*	Arc Welds*
1 x1½ in.	$0.59	$0.51
1¼x1½ in.	0.66	0.30
1½x2 in.	1.13	0.45
1¾x2½ in.	1.25	0.45
2 x6 in.	3.05	0.85

*Labor costs only included.

The following figures were supplied by one of the large American railroads, being taken from jobs at various times and compared with the cost of restoring the apparatus to service by previous methods, either by replacement or repair. The arc-welding costs were based on an hourly power cost of 51c. for the carbon arc and 17c. for the metal arc, together with the cost of direct labor and an overhead charge of 40 per cent. The power costs are somewhat higher than those obtained in average work.

COSTS OF RAILROAD REPAIR WORK

Operation	Cost of Welding	Cost of Replacement or Repair by Former Methods
Welding tender draft casting	$ 1.11	$ 18.31*
Welding tender center draft casting	4.36	19.06*
Welding tender draft arm	1.11	19.08*
Plugging 51 holes in expansion plate, hole 1 in. dia. by ½ in. deep	2.75	10.15
Repairing mud ring	6.50	34.57†
Building up flat spots on locomotive drivers	.40	225.00‡
Building up four piston valve flanges	9.52	24.20*
Repairing mud rings	5.57	32.70†
Plugging four holes 2 in. dia. by 4 in. thick	1.16	4.44
Cutting four 6 in. holes in tender deck sheets ½ in. thick	1.08	8.35
Plugging holes in two driving-box cellars	.55	2.55
Welding eccentric strap, broken through neck	1.08	41.28*
Building up jaws of two pedestal caps	3.49	10.00
Welding one driving box for type K-2 locomotive, broken through crown	5.75	39.31*
Welding frame stiffener on locomotive	3.29	14.73
Welding main rod, broken through end	6.35	70.49*
Repairing firebox	134.89	869.58§
Welding two spokes in trailer-wheel center	7.72	68.05*
Welding two spokes in driving-wheel center	7.98	99.98*
Welding three spokes in driving-wheel center	11.20	126.60*
Welding two spokes in driving-wheel center	5.13	112.09*
Welding cracks in bulkhead in tender crank	2.33	8.00
Welding cracks in side and door sheets of firebox	4.23	24.35†
Welding bridge in flue-sheets	2.88	20.12†
Welding cracks in side sheets	26.15	31.79
Repairing air drum	2.83	12.64*
Welding guide yoke	1.68	16.15†

*New parts required. †Repair. ‡Estimated cost to turn down all drivers as would otherwise be required. This would means also the loss of at least one year's wear on the tires. §New firebox required.

The Thomson Electric Welding Co., which was the pioneer in this process and which has therefore had the greatest experience in this field, presents the following as covering the metals and alloys that can be welded:

Metals: Wrought iron. Cast iron. Wrought copper. Lead. Tin. Zinc. Antimony. Cobalt. Nickel. Bismuth. Aluminum. Silver. Platinum. Gold (pure). Manganese.

Alloys: Various grades of tool steel. Various grades of mild steel. Steel castings. Chrome steel. Mushet steel. Stubs steel. Crescent steel. Bessemer steel. Nickel steel. Wrought brass. Gun metal. Brass composition. Fuse metal. Type metal. Solder metal. German silver. Aluminum alloyed with iron. Aluminum brass. Aluminum bronze. Phosphor bronze. Silicon bronze. Coin silver. Various grades gold.

Combinations: Copper to brass. Copper to german silver. Copper to gold. Copper to silver. Brass to wrought iron. Tin to zinc. Tin to brass. Brass to german silver. Brass to platinum. Brass to tin. Brass to mild steel. Wrought iron to cast steel. Wrought iron to mild silver. Steel to platinum. Wrought iron to tool steel. Gold to german silver. Gold to silver. Gold to platinum. Silver to platinum. Wrought iron to mushet steel. Wrought iron to stubs steel. Wrought iron to crescent steel. Wrought iron to cast brass. Wrought iron to german silver. Wrought iron to nickel. Tin to lead. Mild steel to tool steel. Nickel steel to machine steel.

ELECTRO-PERCUSSIVE METHOD OF WELDING

As electro-percussive welding is of more recent origin than any of the other methods, less is known of its ultimate possibilities, more especially with reference to its adaptability.

It will weld any two metals, whether alike or unlike as to their composition, melting point, conductance—in fact, quite

regardless of their characteristics, though such combinations as silver and tin, or aluminum and tin, iron or lead will of course not be permanent any more than they will be when welded by any other method, since their alloys disintegrate in time. Thus far, this method has been largely confined to the welding of small wires or the equivalent, aluminum to aluminum or copper, platinum to nickel or copper, thermocouples, spring steel, etc.

The principle involved is that of percussive contact between two metals with a condenser discharge occurring at the instant of such contact. The various items involved include voltage, velocity and force of impact.

At the instant of contact, the condenser current is so heavy that the ends of the abutting metals are vaporized by the explosive discharge; and, owing to the blow delivered by the falling mass, are forged together. The heat produced, though intense, is developed so quickly that it is confined to the extreme surfaces of the metals and therefore there is no opportunity for unequal heating with its possible deleterious effect on the welded materials.

Cracked and Seized Pistons

In discussing "Cracked and Seized Pistons in Diesel Engines" at the November meeting of the Diesel engine users Association, P. H. Smith remarked that the fundamental cause of cracks in Diesel engine pistons is a highly heated core trying to expand but being restricted in so doing by a comparatively cold and very stiff ring of metal surrounding it. The consequence of the core attaining a higher temperature than that of the remainder of the metal of the piston is distortion and buckling, and in cooling after the engine has been shut down the core does not quite resume its original unstrained condition. This action being progressive with alternate heating and cooling, the stresses become higher until fracture occurs. Diesel engines working continuously day and night give little trouble from cracked pistons as compared with those working more intermittently.

Some builders are endeavoring to find a cast iron for pistons which will not "grow" on repeated heating and cooling. Such an iron is very pure, high in manganese and low in silicon, but being mainly of Swedish origin, is practically unobtainable at the present time. Although Mr. Smith thought that there was much to be said in favor of using such a grade of iron, he did not think that the ultimate solution of the trouble of cracked pistons would be found in the adoption of any particular grade of cast iron.

He then referred to two general systems of construction which have found favor in large pistons; namely, pistons with renewable heads and water-cooled pistons. He himself had not much faith in the renewable head, though it had some advantages. It was introduced, not so much with the idea of preventing fractures as to reduce the cost of replacing a broken piston. It did not remove the cause of cracking, as there was still the very hot core surrounded by a stiff colder ring, though it must be admitted that some renewable heads are designed in such a manner as to carry away a greater amount of heat from the hot core than is possible with ordinary methods of piston construction. He considered as a further objection to the renewable head, the usual soft character of the metal, selected on account of its resistance to fracture; that it would probably be liable to burn in the center, and the wear in the ring grooves in the softer metal would also be more rapid.

He then described an arrangement of a renewable core in the piston head, intended to provide a solution to the cracking trouble. This is made in two parts so as to reduce stresses to a minimum in the core as well as in the piston. The core proper, or inner part, is fixed onto a recess in the piston head by a gas-tight joint well removed from the region of highest temperature and is surrounded by a separate annular ring. The core is free to expand laterally and longitudinally, and the annular ring is similarly unrestricted. To reduce any tendency to crack in the remaining portion of the piston head, the recess which contains the core is stepped, the depths of the steps gradually increasing, and the top edge of the recess is sufficiently removed from the hottest region to avoid cracking.

In the larger sizes of pistons the difficulty is not only to avoid cracking, but seizure, and in the speaker's opinion all Diesel-engine pistons exceeding 16 in. diameter should be water- or oil-cooled if the mean effective pressure is as high as 95 to 100 lb. per sq.in.

Allowable Pressure per square inch ranges from 10 to 30 lb. for high-speed shafts in babbitted bearings, to 100 lb. for large slow-speed shafts. Engine crankpins often sustain 1,000 to 3,000 lb. per sq.in.

Private Company Furnishes Breakdown for City

Considerable discussion is taking place in power circles in the Northwest over the action of the City Council of Tacoma, Wash., in forcing a private power company to connect its lines with the municipal power plant as an auxiliary for the latter in case of breakdown or during peak hours. The Tacoma Railway and Power Co. sought a franchise for tracks on Pacific Ave. to serve the Pacific Heights section of the city and petitioned the City Council for such a right.

Previous to this the municipal power plant had experienced difficulty in serving its patrons during peak hours, and on two occasions the plant had failed and caused merchants considerable inconvenience, and the city lighting department injected into the franchise the provision for connecting the city plant with the other so that the Tacoma Railway and Power Co energy could be used in an emergency. The City Council finally decided that if the franchise was wanted badly enough, the traction company would make an agreement with the city power department, which it did, much against its wishes. For the first 2½ hr. during a breakdown of the city plant the private company will receive ¾c. per kw.-hr. in addition to a certain sum per kilowatt of demand.

ENGINEERING AFFAIRS

The Indiana Engineering Society will meet Feb. 2 to 5 at the Claypool Hotel, Indianapolis. A joint session will be held with the Indiana Water-Supply and Sanitary Association on Feb. 4, also a joint banquet. A good program is promised, which will be announced later. A feature of the convention will be the exhibits, and those desiring to show work, material, etc., of interest to the engineers and public officials, can obtain information from Charles Brossmann, 1616 Merchants Bank Building, Indianapolis, secretary of the Indiana Engineering Society, and Dr. W. S. King, State Board of Health, secretary of the Indiana Water-Supply and Sanitary Association.

The Washington Society of Engineers held its annual meeting at the Cosmos Club Wednesday evening, Dec. 15, 200 members and guests being present. After the reading of the reports of the committees the following officers were elected for the ensuing year: President, John C. Hoyt, hydraulic engineer, Water Resources Branch, Geological Survey; vice-president, Albert L. Baldwin, computer, Const. and Geodetic Survey; secretary, Frederick W. Albert, engineer, Water Department, District of Columbia; treasurer, C. B. Mirick, vice-president, National Electrical Supply Co. Directors: Elliot Woods, superintendent Capitol buildings and grounds; Morris Hacker, inspector of buildings, District of Columbia; and T. H. Taliaferro, professor of civil engineering, Maryland Agricultural College. During the evening W. H. Cowling, official photographer for the United States Reclamation Service, gave an exhibition of moving pictures of the Grand Cañon and the Yosemite Valley taken by him last summer, this being the first public exhibition of the pictures. At the close of the meeting a buffet luncheon was served. The Washington Society of Engineers, which was organized ten years ago, has a membership of 412.

U. of I. Research Fellowships—To extend and strengthen the field of its graduate work in engineering, the University of Illinois has since 1907 maintained ten research fellowships in the Engineering Experiment Station. By action of the board of trustees on Mar. 9, 1915, four additional fellowships were created, making fourteen in all. These fellowships, for each of which there is an annual stipend of $500, are open to graduates of approved American and foreign universities and technical schools. Appointments to these fellowships are made and must be accepted for two consecutive collegiate years, at the expiration of which period, if all requirements have been met, the master's degree will be granted. Not more than half of the time of the research fellows is required in connection with the work of the department to which they are assigned, the remainder of the time being available for graduate study. Nominations to fellowships, accompanied by assignments to special departments of the Engineering Experiment Station, are made from applications received by the director of the station each year not later than the first day of February. These nominations are made within the month of February by the station staff, subject to the approval of the faculty of the graduate school and the president of the university. Appointments are made in March and take effect the first day of the following September. Vacancies may be filled by similar nominations and appointments at other times.